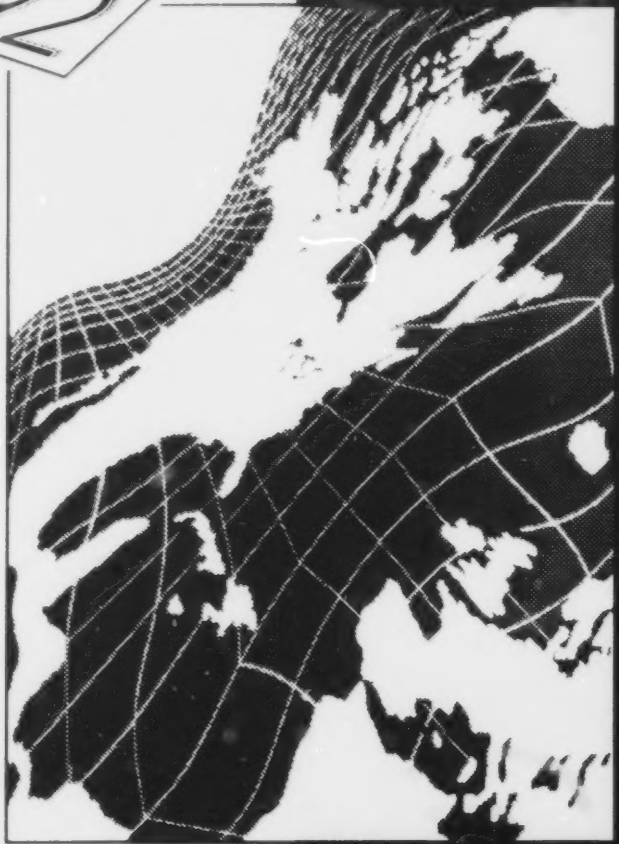
GIS SIG 92

THE CANADIAN CONFERENCE ON GIS

PROCEEDINGS

March 24-26, 1992 - Ottawa



Canada

Organized by
The Surveys, Mapping and Remote Sensing Sector, EMR Canada

in cooperation with

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING

and
the Inter-Agency Committee on Geomatics

Conférence organisée par
le Secteur des levés, de la cartographie et de la télédétection, EMR Canada

en collaboration avec

ASSOCIATION CANADIENNE DES SCIENCES GÉOMATIQUES

et
le Comité mixte des organismes intéressés à la géomatique

Du 24 au 26 mars 1992 - Ottawa

ACTES

LA CONFÉRENCE CANADIENNE SUR LES SIG

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MUNICIPAL GIS: DESIGNING THE CITY-WIDE DATA MODEL

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ABSTRACT

The City of Scarborough, when it considered the introduction of a Geographic Information System, first sought to understand the business activities of each, and all, the disparate components that make up the corporation. This two year study resulted in individual Information Resource Plans (IRP) for each Department. A third year was spent in reconciling the many separate documents and creating a high-level Conceptual Data Model for a Corporate Information System. Of the thirteen broad data groupings, four were assigned to the GIS Group for the design of Detailed Data Models and to populate the resultant databases. The GIS Group, in fact, were to initiate the new Information System for the entire City. The Modelling Sessions involved hundreds of Users from the entire User community in small and large groups, in intensive entity definition activities, in technical review sessions and in the general examination of context. By involving so many users in the earliest Conceptual Modelling stages and not just in the development of Prototypes and Applications, GIS has become an accepted, supported and essential component of the City's Information System strategy.

RÉSUMÉ

Lorsqu'elle a examiné la possiblité d'implanter un système d'information géographique (SIG), la ville de Scarborough a d'abord cherché à comprendre les activités de chacun et de la totalité de ses composants. Cette étude, qui a duré deux ans, a donné lieu à des plans de ressources d'information individuels pour chaque département. On a consacré une troisième année à concilier ces nombreux documents disparates et à créer un modèle de données conceptuelles évoluées exploitable par un système d'information global. Quatre des treize grands groupes de données ont été confiés au Groupe SIG qui devra concevoir des modèles de données détaillées et charger les bases de données résultant de l'opération. Le Groupe SIG, en fait, devait créer le nouveau système d'information pour l'ensemble de la ville. Les séances de modélisation ont amené des centaines d'usagers provenant de l'ensemble de la collectivité des utilisateurs, par petits et grands groupes, à prendre part à des activités intensives de définition d'entités, à des séances d'examen technique et à l'analyse générale du contexte. En impliquant tant d'usagers au premier stade de la modélisation conceptuelle et non simplement à l'étape de l'élaboration des prototypes et des applications, on a fait du SIG un composant accepté et essentiel de la stratégie de la ville en matière de système d'information.

INTRODUCTION

An information system collects and stores data on objects and events. It processes the data to produce information supporting the activities of an organization. When it becomes necessary to make very extensive revisions to an existing Information System, especially when those changes affect large numbers of users, the user community must be actively involved in the design and implementation of the new system [Kroenke 237]. Most users, however, have no knowledge of the technical aspects of system development, nor do they feel qualified to accept or reject specifications before implementation. One method of achieving a high level of user involvement is through focused projects using common, understandable terminology and communication tools.

Municipal governments are very complex organizations. Larger municipalities may have thousands of employees, tens of millions of dollars worth of physical plant to maintain and hundreds of separate activities and responsibilities. The municipality may provide service to between hundreds and hundreds of thousands of constituents. Information Systems to support these activities are correspondingly large and daunting to individual users. One communication tool by which the municipal structure can be well understood by its operations staff and executive, as well as by Information Systems personnel, is the Data Model. The Data Model divides the organization into Subject areas or Databases which relate to recognizable organizational subjects (eg product inventory, personnel) rather than to conventional computer applications [Dutka 5].

The City of Scarborough has aggressively pursued the development of the City-wide data model. The GIS Group, in particular, has used Data Modelling techniques to actively involve users and to validate the recommendations for new system implementation.

THE MUNICIPALITY

The municipality is a geographic area created through specific legislation within which are situated buildings, transportation networks, infrastructure and a host of other objects. It is a place where people congregate, whether to live or to work. Some cities, usually large or critically situated metropolitan areas, form the commercial, cultural, industrial and social centre for a large hinterland. These act as part of a network of World Cities [Hall].

Smaller municipalities require many of the objects found in the big cities but on a proportionately smaller scale. Despite any similarities, however, the economic base, the physical area and population of each municipality is different. As a result, occupants of the municipality have different priorities and have created a bureaucracy with an unique mandate and a different internal organizational structure from other municipalities.

Municipal Activities

Typical municipal responsibilities include: the construction and maintenance of physical infrastructure, such as roads and sewers; the protection of life and property through emergency services such as police, fire or ambulance; control of physical development through land use planning; the provision of recreation facilities and experiences, such as parks or community centres as well as recreation programmes; the support of health and welfare through the provision of public health clinics, animal control pounds and garbage collection; the coordination of public transportation; and, the assuring of public safety through the issuing of building permits and through fire, health and building inspection.

Support for these responsibilities is provided in much the same way as in any corporation: through internal organizational units dealing with Personnel, Inventory and Fleet Maintenance, Law, Finance and Accounting, Building/Property Management and even Public Relations/Marketing/Communications.

All municipalities are operated within a corporate structure. Many municipalities are formally incorporated. The corporate board is actually a Council of elected representatives with the employees divided into various departments, divisions or other workplace designations. Some municipal functions are the responsibility of affiliated Boards or Commissions such as Library Boards, Planning Boards, Parks Boards or Public Utilities Commission. Some public functions at the municipal level are directly controlled by senior levels of government. In Ontario, for example, school boards are under the provincial Ministry of Education, hospitals are under the Ministry of Health and property assessment is under the Ministry of Revenue.

In the situations where regional municipalities have been formed, some responsibilities are separated, some are duplicated and some are taken over by the next level of government. Some regional municipalities hold absolute control over their component municipalities on such issues as land use planning, the provision of emergency services or taxation. Other regional municipalities will merely co-ordinate the individual activities of the component municipalities and/or directly manage the largest scale of physical services such as the regional roads, the regional parks and recreation facilities, the trunk water mains and sewers, and some tourist attractions.

Determining exactly how to best provide the services required by the municipality's constituents requires data about the municipality: demographic statistics, knowledge of the structures, businesses, existing and proposed land uses and physical features. This information often has to be coupled with trends that may be applicable throughout the region, or the continent, or only very locally. Facts are often supplemented by local research efforts for individual projects or ongoing sampling procedures by various municipal departments.

Municipal Information Systems

Large municipal Information Systems have, in the past, tended to be similar to most corporate systems, with an emphasis on financial reporting, such as General Ledger or payroll, and personnel records. Although "financial" includes Tax Management, these systems dealt primarily with the internal support components of the City and not with the business of the municipality itself. There was little opportunity to share data. Systems relating to the actual responsibilities of the City tended to be very specific programmes, the supporting data for which was often redundantly stored and maintained for several different projects or activities. For a number of reasons, small, independent, PC-based applications proliferated with the introduction of general office automation. Specialized information systems for Computer Assisted Drafting and Design (CADD) were been introduced to the work environment, often without any direct connection to other City databases.

By the mid-1980's the situation in many large municipalities was a huge mass of data stored many times by many individuals. It was realized that it was necessary to restructure information systems to allow for greater sharing of data, computer hardware and computer programmes.

Generally, rebuilding the systems involved a certain amount of introspection. Some municipalities retained consultants, others hired contract staff and still others used existing staff, augmented as necessary, to examine the organization's business functions. This resulted in a Business Definition, and, ultimately, a recommended Technology Architecture appropriate to each city. In most cases, the final result was a synthesis of existing systems, some recognition of new technology, and the introduction of off-the-shelf solutions specific to certain city activities.

Most municipalities relied heavily on process modelling or suite-of-application coordinating. Scarborough, however, elected to place its emphasis on development of the Data Model.

DATA MODELLING

Models are simplified representations of the complexity inherent in reality. Typical models are the drawings, mock-ups and prototypes prepared by Engineers or Architects. These models serve as: a basis for discussion of requirements with the client; a basis for defining the appearance or design of the product; a tool for representing and evaluating specific concepts; an indication of the scope of the product; a basis for estimating costs; specifications for the builder; or a basis for testing the product (in the case of prototypes) [DMR 17].

The Data Model is a representation of the data used and created by the City. It describes the things and events of importance to the City of Scarborough. The structure of the data is independent of:

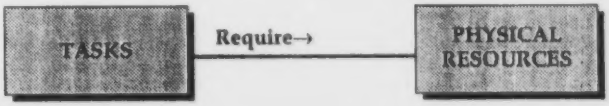
- functions (manual or automated) which operate on the data
- the computer technology used to implement the resulting databases
- the organizational structure of a department

The Data Model demonstrates that data is not "owned" by an application or computer system. Some applications create data that other applications must use. Viewing data as "owned" by an application can result in fragmentation and duplication of data. Viewing the data as a city wide resource helps promote the sharing of required data [City A-6].

The Data Model is composed of:

- a data model diagram of major groupings of data (subject databases) and the relationships among them,

  a typical example of part of which would be:



  and,
- a supporting narrative that describes the content of each subject database.

Languages have been developed to accommodate users who are not necessarily experienced software engineers. Tools have been built around the languages to generate automated requirements, integration and analysis mechanisms based on "top-down", multi-phased design to support the software engineering process [King & McLeod 316]. This is sometimes described as "semantic" modelling. Semantic Models were invented specifically to make database design more accessible to non-database specialists, such as users, conceptual designers and even application specialists. Semantic models typically represent the application environment as a collection of objects (entities), the "things" of interest to each user. Objects are typically interrelated, in a Data Model, via attributes (inter object mappings), and are classified according to types (classes) and sub-types (sub-classes) [King & McLeod 315].

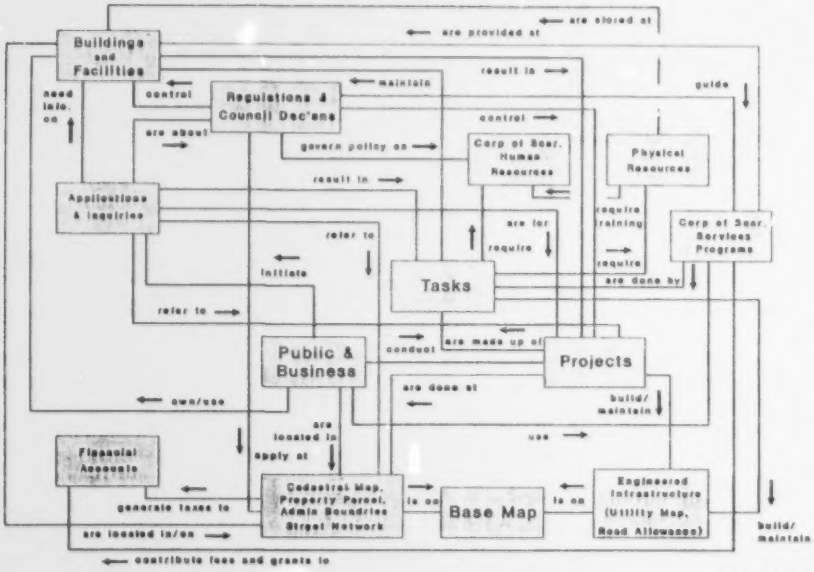
Database methodology continues to increase in sophistication. Early data processing applications utillzed a separate file, or group of files, for each application. The design was generally simple and easy to implement. Such a design, however, resulted in data redundancy and high maintenance costs [Dutka 5]. Traditional system development models have tended to emphasize process, the flow chart representing the sequence of events inherent in the creation, storage, modification and use of data [Thompson 67]. Although this is important, especially at the point at which the system is actually built, a danger exists that this approach could address solutions before completely identifying the needs and problems. The focus is on existing practises, existing organizational structures and existing systems: the "bottom-up" approach. The "top-down" approach begins at the highest, or most general level and then is broken down into successively simpler chunks.

The business activities of the system being created will dictate the data requirements, but, in the

long run, it is the data rather than the processes, which remain stable the longest in most organizations [Quarles & Ny].

The City, for example, provides Recreation Programmes in Facilities. The Data Model provides a "home" for each of the bits of the picture without having to duplicate anything. Scarborough's City-Wide Data Model is shown below.

City of Scarborough: Corporate Data Model



[City A-7]

The property on which the facility is located is in **CADASTRAL**. The facility, itself is found in **STRUCTURES**. The recreational programme, if administered by the City, is in **SERVICES & PROGRAMS**, or if simply scheduled-out to a sports league, in **APPLICATIONS / INQUIRIES / PERMITS**. The design and construction of a new facility is in **PROJECTS**. Maintenance or inspection of existing parts of a facility are in **TASKS**. The fees, or maintenance costs associated with the facility are in **FINANCIAL ACCOUNTS**. The staff organizing or leading the program are in **HUMAN RESOURCES**. The portable tools, equipment and materials needed to run the program or maintain the facility are in **PHYSICAL RESOURCES**. Participants are in **BUSINESS & PUBLIC**. Policy, procedure and level of service are found in **REGULATIONS**. The site or building is serviced by **ENGINEERING INFRASTRUCTURE**. The context of the entire area is visible on the **(TOPOGRAPHIC) BASE MAP**.

Methodology

The City of Scarborough adopted, as its standard for the development of information systems, use of the methodology Productivity Plus® developed by the DMR Group and the Computer Assisted Software Engineering (CASE) tool EXECELERATOR. This method was selected because it is more data driven than application driven. The DMR nomenclature, to which the City of Scarborough subscribes, refers to Entities linked by Relationships and described in a Data Dictionary.

In DMR's Productivity Plus®, the Subjects represent the broadest categories into which the organization's data can be divided. Conceptual-level models divide each Subject into classes, or categories, referred to as Facets. The Facets house the Entities. Graphic representations are created to show the Subject within the context of the other Subjects and outside data stores, the individual Facets within the Subject and the individual Entities within the Facet. Definitions are created for each Subject, each Facet and each Entity. Attributes are assigned to each Entity, at least one of which is termed a Key Attribute. Relationships within, and without, each Subject and Facet are described [DMR 60].

To be effective as a true implementation framework, the Data Model must be "normalized", that is, comprised of Entities refined to, in database terminology, Normal Form. Normalized Data Entities occur only once in the entire Data Model. Relationships are examined and, wherever two entities correspond directly only one to the other, say an Assessed Property and its Assessment Roll Number, the two Entities are merged. The Assessment Roll Number becomes an attribute of Assessed Property. Reducing the Data Model through First, Second and Third Normal Forms is time consuming and must be led by an experienced designer [Dutka 37] but it can be done by Users. At the City of Scarborough, User Analysts brought all data to at least First Normal Form. Further Normalization was done by the GIS Analysts and Systems Analysts as part of the rationalization of the four GIS Subject Databases.

The benefits of Data Normalization are expected to be:

- construction of solid relations and the selection of appropriate keys
- identification of good interfaces for the end user which can accommodate unplanned queries
- reduced problems in inserting and deleting data once the system is in place
- reduced modification time associated with changing the data structure, leading to improved response time [Dutka 9]

To be deemed truly normalized, all attributes of an Entity must depend solely on the identifier, or Key Attribute, and no other attribute. This is an application of the third normal form rule for elimination of transitive dependencies. If an attribute depends on another attribute that is not the identifier, or if one or more attributes of the entity could constitute a new entity of interest in itself, these attributes give rise to additional entities [DMR 72].

Data normalization proved to be an analytical technique useful during Scarborough's data modelling exercise. The viewpoints and requirements of the user were considered as part of the

database design process. The appropriate attributes and relationships among these attributes were identified and designed. The user's view of the data was not inhibited by technical hardware or software limitations.

THE SCARBOROUGH EXPERIENCE

Information Resource Plans (IRP)

Throughout 1987 and 1988, the City of Scarborough Information Systems staff, at first in conjunction with a consultant, carried out a department-by-department examination of its systems requirements. Each department was obligated to undergo this examination and to fund the study independently. In most cases all the senior staff of each department were interviewed, often more than once, and in many situations, all managers and many actual user-employees participated. This resulted in twelve Information Resource Plans.

Corporate Strategic Information Resource Plan

During 1989, a Corporate Information Resource Plan was created by combining all of the individual IRP's done for each department. While this corporate plan was being created, the City undertook a parallel study examining the potential for a Geographic Information System in the City. The GIS Study brought out some system needs not previously identified in individual departmental IRP's, primarily because of the cross-departmental nature of GIS. The corporate study itself revealed a great amount of redundancy in data requirements. Part of the corporate Information Plan involved the construction of a City-wide Data Model. The Model attempted to represent overall, corporate requirements and information processes rather than the individual data needs expressed by the separate IRP's. It also attempted to limit some of the inconsistencies in the departmental studies.

Four of the Subject Databases were land related, and, as such, deemed to be the responsibility of the GIS group. It was anticipated that users would frequently require access to these databases for most, if not all, typical queries or other applications. These four were called:

Topographic Database
Cadastral Database
Structures Database, and
Engineering Database.

Nine databases were deemed to be "general" in nature, that is, not specifically land related. These were identified as:

Regulations Database
Financial Database

Physical Resources Database
Human Resources Database
Projects Database
Tasks Database
Application and Inquiries Database
Programmes and Services Database
Business and Public Database

Scarborough's GIS undertook to create Conceptual, Functional and part of the Physical-level data and process models for each of the four land-related Subject areas. The stated mission of the entire GIS effort was *"to create the best user-oriented and user-defined municipal Geographic Information System in North America"*. The System was to be in place and fully operational by December 1993.

User Involvement

Companies can survive the dynamic business environment and the information explosion only if users are directly involved in the development and use of application and databases. Users need to be involved, they have the right to be involved, and they have a responsibility when involved. When this involvement is maximum, the company will succeed [Brackett 193].

If users are to design and maintain their own systems, they have the responsibility to learn and use the proper design methods and techniques. It is the professional's responsibility to define methods that are easy to understand and use and to train users in those methods. The users must be committed to using those methods [Brackett 193].

One GIS user involvement method was the modelling of data, Subject Database by Subject Database. In most cases, this was done by putting together a team of users from diverse areas of the corporation and, with the help of a GIS facilitator, debating and recording the relationships among various entities. When this approach was used, the team would meet daily, each morning for three hours, for as long as seven weeks, hammering out definitions, relationships and cardinality.

Although each modelling project was handled somewhat differently, following the production of a first draft of each subject Model, other users from departments which would likely be affected were given presentations of the Models. Workshops were held, as often as possible with groups of diverse users, in order to recreate some of the experience of the intensive Team debate. Commonly, these workshops involved groups of between 8 and 12 eventually dealing with more than a hundred individuals for each Subject.

It is important to realize that geographic information is the lifeblood of a municipality. It is possible that 80% of the activities of municipal employees centres around specific locations or physical features. Workshops participants included public health nurses, fire fighters, sanitation collection staff, animal control officers, recreation supervisors, equal opportunity monitors and

the whole range of skills and professions existing in a complex municipality.

One serious difficulty was that many individual and professional disciplines define specific words differently. The terms defined in the documents represented a consensus and related to their functions in the specific Models created. The meaning and definition of words could, arguably, have been the most important point of understanding and misunderstanding among different disciplines.

The projects in 1990 and 1991 identified conceptual-level data entities, their relationships and data element descriptions. They also identified those subsystems and functions inherent in the related processes concerning those elements within the four GIS Subject areas.

Rationalization

The completion of the Conceptual Data and Process Modelling resulted in four reports, each containing models, definitions and comments. Each of the four models referred to specific entities in the other 12 databases. It was necessary to review each of the four GIS-type models, revise them as appropriate to bring them each to a common level of detail, normalize each of them and then rationalize all four together to avoid any redundancy or repetition of data elements. This was done by a special team of Information System and Geographic Information System Business Analysts, Data Analysts, System Analysts and GIS Analysts assisted through a CASE tool.

The revised model, newly normalized and rationalized, was subsequently used in two ways. The Information Systems staff incorporated it into the City-Wide Data Model, to which would relate the nine non-GIS subject databases. The GIS Group proceeded with the Functional Modelling for each of the subject areas.

CONCLUSIONS

Scarborough discovered that Conceptual Data Modelling led to a very deep understanding of the business activities of the organization and especially to the very different data requirements among its various players. The debates themselves led to personal understanding among the various parties which will likely remain throughout the period of development and implementation.

Individuals who may not have had much cause to work together during their normal activities had laboured at length about what they do for a living. In some ways this replaced the "informal" network among specific individuals with a permanent level of personal respect among different departments and professions. Users, who, in the past would have resisted using data generated elsewhere as "not good enough" are now far more likely to trust the data in the system because they feel all parties understood their needs and concerns.

Individual users developed a good appreciation of the concepts of data modelling and a grudging respect for the work done by Information Systems staff. It became clear that the municipality was not merely a collection of isolated fiefdoms but an organic whole where sharing and cooperation leads to better productivity, better service to the public and more time spent in one's chosen field of expertise.

The Data Model itself has proven to be an excellent means by which the City's Data requirements can be separated and related. The development of individual systems or application programmes is expected to become a relatively straightforward effort. Having identified all of the data required for each application in a normalized fashion, assembling the data from the various repositories as needed is a matter of examining the Data Model in much the same way that one would utilize a Road Map.

The City will decide on a final Technology Architecture in the near future. Should this architecture prove to be centralized, or decentralized, the Data Model need not be altered until the Business Activities of the corporation change. Similarly, responsibilities moved from one organizational unit to another, such as the creation of new Departments or the elimination of existing Departments does not have an impact on the Model because it deals with data, not individual processes or applications.

Data Modelling has allowed different groups, such as the GIS Group, to define data repositories, functional design and even physical systems without duplicating efforts to be undertaken by other groups. Any data which must be created for immediate needs will always be housed in its final home when the entire Systems Architecture is in place.

ACKNOWLEDGEMENTS

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An Advanced Software Engineering Environment for Prototyping and Development of GIS Applications

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Abstract

The exploitation of Geographic Information Systems (GIS) technology is heading into its third decade. It is now considered by many an all encompassing base technology similar to Computer Aided Drafting (CAD) and Relational Data Base Management (RDBM) systems used for both traditional and new types of applications. Although there are still requirements for so-called "turn-key" applications, the modern approach is to instead provide an advanced software engineering environment that is embedded into the GIS. This advanced software engineering environment would provide tools at a variety of levels that may be used for prototyping and development of georeferenced and non-georeferenced applications. At the lowest level, a run-time subroutine library accessible by several programming languages and debuggers would be used by computer systems staff. The highest level of tools consisting of pseudo Computer Aided Software Engineering (CASE) based source code, user-interface, and query generators would be used primarily by end-user and operations staff. In addition to supporting the development of applications, the advanced software engineering environment may also be used for integrating external applications in an enterprise-wide GIS. This paper discusses the new generation of tools required in an advanced software engineering environment, their features and limitations, some sample applications, and of course what this means to an organization.

Biographical Sketch

John Smyrnew is a Principal Application Specialist with GeoVision Corporation. John received a Bachelor of Arts (Honours) in Geography and Masters of Arts in Cartography from the University of Ottawa. He worked for seven years with the Province of Alberta as a Programmer, Systems Analyst, and Project Manager, responsible for the design and implementation of several automated mapping and geoprocessing systems used in non-renewable and renewable resource management applications. He also lectured for three years at the University of Alberta in computer-assisted mapping and geographic information systems. John joined GeoVision Corporation in 1985 as a Project Manager, overseeing the implementation of entire automated mapping and geoprocessing programs. He is currently responsible for defining requirements, design of applications, and development of related software tools.

Environnement d'avant-garde en ingénierie du logiciel - Création de prototypes et élaboration d'applications de SIG

RÉSUMÉ

L'exploitation de la technologie des systèmes d'information géographique (SIG) entre dans sa troisième décennie. Elle est désormais considérée par bon nombre de personnes comme une technologie de base complète et semblable au système de dessin assisté par ordinateur (DAO) et au système de gestion de bases de données relationnelles (SGBDR) utilisé pour les applications classiques ou nouvelles. On a encore besoin d'applications dites "clés en main"; cependant, l'approche moderne consiste plutôt à intégrer un environnement de pointe en ingénierie du logiciel dans le SIG. Grâce à ce dernier, les usagers disposeront d'outils à divers niveaux qui leur permettront de créer des prototypes et d'élaborer des applications avec ou sans référence géographique. Au niveau inférieur, le personnel exploitant les systèmes informatiques auront accès à une bibliothèque de sous-programmes d'exécution exploitables en plusieurs langages de programmation et à des logiciels de mise au point. Les outils les plus évolués, c'est-à-dire le code source basé sur pseudo CASE (Computer Aided Software Engineering), l'interface avec l'utilisateur et les générateurs de systèmes d'interrogation seront exploités principalement par les utilisateurs finals et le personnel d'exploitation. En outre, pour faciliter l'élaboration d'applications, on pourrait mettre à profit l'environnement de pointe en ingénierie du logiciel pour intégrer des applications externes au SIG de l'entreprise. Le présent document traite également de la nouvelle génération d'outils dont il faut disposer dans un environnement de pointe en ingénierie du logiciel, de leurs caractéristiques et de leurs limites; on y trouve également certains exemples d'applications et, bien entendu, des conséquences qu'entraîneront ces outils pour une organisation.

Operational GIS Requirements for City/County Governments

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Abstract

A study was undertaken to determine the operational GIS requirements of medium size and larger City/County governments in North America. The objective of this study was determine a true picture of a typical City/County that could be used for designing and implementing applications. The study was based on the detailed analysis of bid documents, requirement and design specifications, personal interviews, and a variety of other sources. It was determined that operational GIS requirements of a City/County government are fulfilled through applications. Applications may be defined as a set of tools and procedures that may be used to solve a problem. As a result, operational GIS requirements may be viewed in a variety of ways by different user types. These ways include low-level functionality, high-level processes, data translation, feature codes and symbology, integration of third-party software, and interoperability. Furthermore, the entire GIS application development process, not unlike traditional MIS application development is evolutionary often occuring over several discrete phases. This paper describes the operational GIS requirements requested by City/County governments, various sample applications, and provides details on what they actually mean.

Biographical Sketch

John Smyrnew is a Principal Application Specialist with GeoVision Corporation. John received a Bachelor of Arts (Honours) in Geography and Masters of Arts in Cartography from the University of Ottawa. He worked for seven years with the Province of Alberta as a Programmer, Systems Analyst, and Project Manager, responsible for the design and implementation of several automated mapping and geoprocessing systems used in non-renewable and renewable resource management applications. He also lectured for three years at the University of Alberta in computer-assisted mapping and geographic information systems. John joined GeoVision Corporation in 1985 as a Project Manager, overseeing the implementation of entire automated mapping and geoprocessing programs. He is currently responsible for defining requirements, design of applications, and development of related software tools.

Exigences opérationnelles d'un SIG pour la ville ou le comté

RÉSUMÉ

On a entrepris une étude pour déterminer les exigences opérationnelles d'un SIG pour les dirigeants des villes et des comtés de moyenne et grande taille en Amérique du Nord. On a voulu avoir une image exacte d'une ville (d'un comté) caractéristique que l'on pourrait utiliser pour concevoir et mettre en oeuvre des applications. L'étude était fondée sur l'analyse détaillée de documents de soumission, de spécifications de besoins et de projets, d'entrevues avec des personnes et de diverses autres sources d'information. On a déterminé que les applications répondaient aux besoins opérationnels d'un SIG d'une ville ou d'un comté. Par "application", on entend un ensemble d'outils et de procédures permettant de résoudre un problème. En conséquence, les exigences opérationnelles d'un SIG peuvent être vues de diverses façons selon les types d'utilisateurs. On peut penser, par exemple, à des fonctions de bas niveau, à des processus de haut niveau, à la traduction de données, à des codes et à des symboles caractéristiques, à l'intégration de logiciels de tiers et à l'interfonctionnement. En outre, tout le processus de création d'applications pour le SIG, comme la création d'applications SIG, est évolutif et comporte souvent plusieurs étapes. On pourra lire dans le présent document une description des exigences opérationnelles d'un SIG énoncées par une ville ou un comté, divers exemples d'applications de même que des renseignements sur leur signification réelle.

LA GÉOMATIQUE ET LA GESTION DES TECHNOLOGIES DE L'INFORMATION (GEOMATICS AND INFORMATION TECHNOLOGY MANAGEMENT)

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RÉSUMÉ

La phase I (1989-1992) du Plan géomatique du gouvernement du Québec vise à pallier au plus urgent et à préparer l'avenir. Dans ce contexte, le ministère des Communications du Québec a entrepris plusieurs travaux de base ayant pour but d'appuyer les efforts de géomatisation de la communauté gouvernementale. Ces travaux portent notamment sur la diffusion et la commercialisation des données, les aspects juridiques de la diffusion, une grille d'évaluation des progiciels de géomatique, la gestion de l'intégrité des bases de données, la conversion des données, les impacts du NAD 83 dans le développement de systèmes, la gestion des expérimentations, le guide développement d'un système d'information à référence spatiale ainsi que sur une méthode d'estimation de la rentabilité d'un investissement en milieu gourvernemental (incluant un modèle des coûts et des bénéfices et la technique de quantification et de calcul de la rentabilité). La présente conférence donne donc un état d'avancement des principaux travaux réalisés en géomatique jusqu'à maintenant.

ABSTRACT

The object of Phase 1 (1989-1992) of the Québec government's Geomatics Plan is to focus on the most urgent needs and prepare for the future. The ministère des Communications du Québec has therefore launched a series of initiatives designed to facilitate the introduction of geomatics-related information technologies in the Québec government. Essentially, these projects centre on the dissemination and marketing of information, the legal aspects of dissemination, a GIS software package evaluation model, the management of the data-base integrity, data conversion, the impact of NAD 83 in the implementation of information systems, an experiment management guide, a guide for spatial information systems design and implementation, and a model for assessing the cost and benefit of government investment projects, including a technique for quantifying and computing profitability. This presentation is a progress report on the main geomatics projects carried out so far.

MODELLING NATIONAL ATLAS OF CANADA DATA AT 1:7 500 000

MODÉLISATION DES DONNÉES DE L'ATLAS NATIONAL DU CANADA À 1/7 500 000

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Abstract

Since 1906, National Atlas of Canada thematic information has been available in map form. During the past three years, the National Atlas Information Service (NAIS) has been converting part of the information from the fifth edition into digital files. This information will be used as a source of data in the database design project which is now underway. One of the challenges of this project is to model the relationships between base components, thematic components and attributes so that they can be stored efficiently in a data base and retrieved for a variety of applications.

This paper describes the diversity and complexity of the data to model, indicates the principal decisions affecting the data modelling, identifies the entities (spatial data), their attributes, and their relations, and finally presents the proposed conceptual data model.

Résumé

Depuis 1906, l'information thématique de l'Atlas National du Canada est disponible sous forme de cartes. Durant les trois dernières années, le Service d'information de l'Atlas national (SIAN) a converti une partie de l'information de la cinquième édition en fichiers numériques. Cette information sera utilisée comme source de données dans le cadre du projet de conception d'une base de données qui est actuellement en cours. Un des défis de ce projet est de modéliser les relations entre les composantes de base, les composantes thématiques et les attributs afin de pouvoir les emmagasiner efficacement dans une base de données et de les extraire pour une variété d'applications.

Le présent article décrit la diversité et la complexité des données à modéliser, indique les principales décisions affectant la modélisation des données, identifie les entités (données spatiales), leurs attributs, et leurs relations, et finalement présente le modèle conceptuel des données.

1. Introduction

Le Service d'information de l'Atlas national (SIAN) est principalement connu pour ses produits traditionnels, à savoir les cartes papier de l'Atlas national. Un programme de l'Atlas national existe depuis le début du siècle, et, à ce jour, quatre éditions ont été publiées soit celles de 1906, 1915, 1957 et 1973. La cinquième édition est en cours, et devrait être terminée en 1992. Quoique la cinquième édition ne soit pas achevée, plusieurs cartes sont déjà disponibles puisqu'elles sont produites et publiées de façon individuelle.

De plus en plus, la production de cartes doit se faire avec l'apport de nouvelles technologies numériques. Le SIAN s'est en effet engagé à produire des cartes grâce aux techniques de publication électronique. Dans ce but, des informations de base telles l'hydrographie ont été numérisées et sont de plus en plus utilisées par les géographes et cartographes; des informations thématiques diverses y sont superposées. Ceux-ci ont découvert le potentiel des outils informatiques pour développer et visualiser plus rapidement ce que pourrait être le produit final.

Pendant que cette numérisation de données existantes avançait, on a vu apparaître de plus en plus de requêtes pour de nouvelles sources de données. Comme les données numériques permettent une plus grande flexibilité dans leur manipulation, il est plus facile de répondre à des requêtes spécifiques; de plus, les exigences des usagers sont devenues de plus en plus variées.

Suite à cette évolution rapide, le SIAN s'est retrouvé dans un nouvel environnement où le milieu de travail, la façon de faire, ainsi que les rapports avec ses clients étaient grandement modifiés.

La plus grande part du travail numérique fait jusqu'à ce jour visait avant tout à répondre aux besoins cartographiques du SIAN. Le but était d'utiliser cette technologie pour accélérer le processus cartographique. Comme les besoins en données numériques dépassent ce seul aspect, il est devenu important d'y regarder de plus près et d'élaborer une stratégie globale.

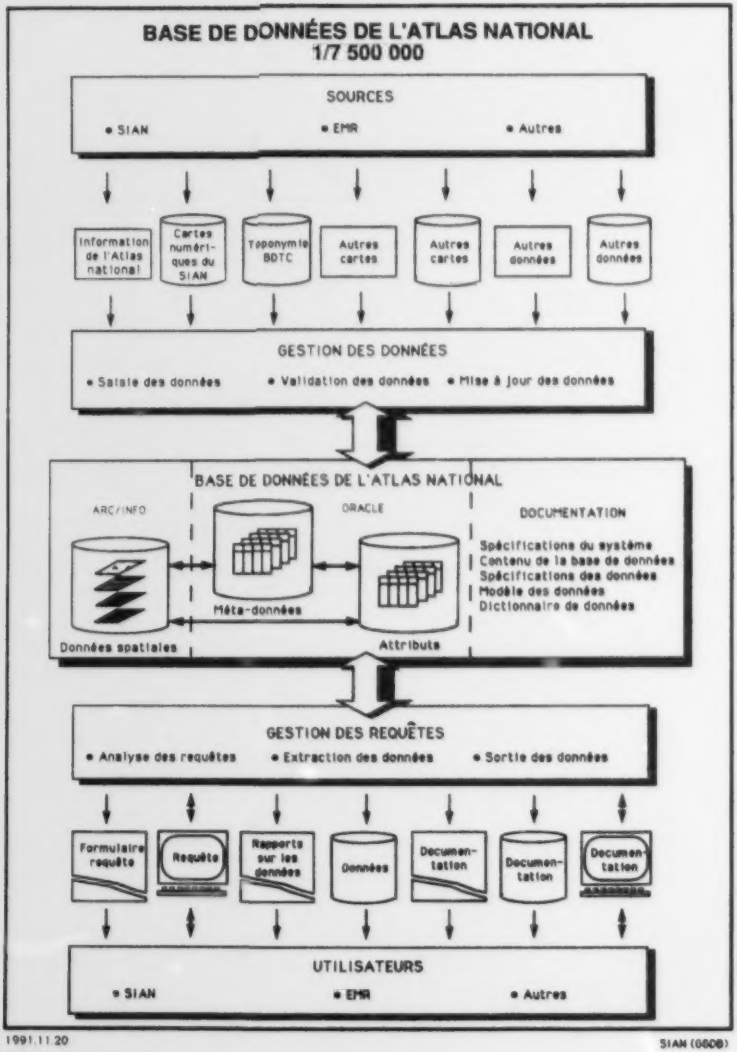
Une équipe multidisciplinaire, comprenant trois géographes, un informaticien, un cartographe et une arpenteur-géomètre, a été mise sur pied; son mandat premier était de fournir une orientation quant aux développements à entreprendre dans les années à venir. Un des principaux projets identifié par le groupe fut la mise en place d'une base de données thématiques à l'échelle de 1/7 500 000 (nous y ferons référence sous l'abréviation BDAN pour Base de données de l'Atlas national). À noter qu'à la suite de ce projet, un autre sera entrepris pour une base de données à l'échelle de 1/2 000 000.

2. Projet de conception de la base de données à 1/7 500 000

Afin de mieux répondre à de multiples exigences, le SIAN a entrepris de structurer les données selon les exigences d'utilisateurs de SIG et d'implanter un système de base de données assurant la protection, la mise à jour et l'accès facile aux données. Le schéma général de cette base de données se trouve à la page suivante.

Le projet a débuté en septembre 1990 et à ce jour, plus de 1,5 année-personne y a été consacrée. L'équipe du projet est maintenant à finaliser la modélisation des données qui seront initialement contenues dans cette base de données.

Graphique 1



1991.11.20

SIAN (0008)

La BDAN sera la source officielle de données à cette échelle. Les différents utilisateurs de ces données devront s'y approvisionner s'ils veulent obtenir les données les plus à jour, et qui répondent aux critères d'acceptation de l'organisation.

Il est très facile, dans ce nouvel environnement numérique, de perdre le contrôle de la gestion des données produites, et de se retrouver avec de multiples spécifications de données, méthodes de numérisation et copies de fichiers. Le but principal du projet est donc de rationaliser la production et la gestion de données numériques produites dans le cadre du programme de l'Atlas national. Comme pour la cinquième édition traditionnelle de l'Atlas national, le contenu sera validé et mis à jour régulièrement par le SIAN. Le SIAN sera en mesure de supporter aussi bien ce produit que les produits traditionnels.

La BDAN deviendra rapidement une source d'information pour la conception de nouveaux produits, et pour offrir divers services à la clientèle de données numériques.

Ce projet de développement comprend les étapes présentées à la page suivante.

3. Complexité des données à modéliser

La modélisation de l'information joue un rôle primordial dans la conception d'une base de données numériques. Afin de pouvoir réaliser cette étape efficacement, il faut posséder une connaissance approfondie des données. La diversité et la complexité des données qui feront partie de la base de données de l'Atlas national doivent être analysées de près lors du processus de modélisation.

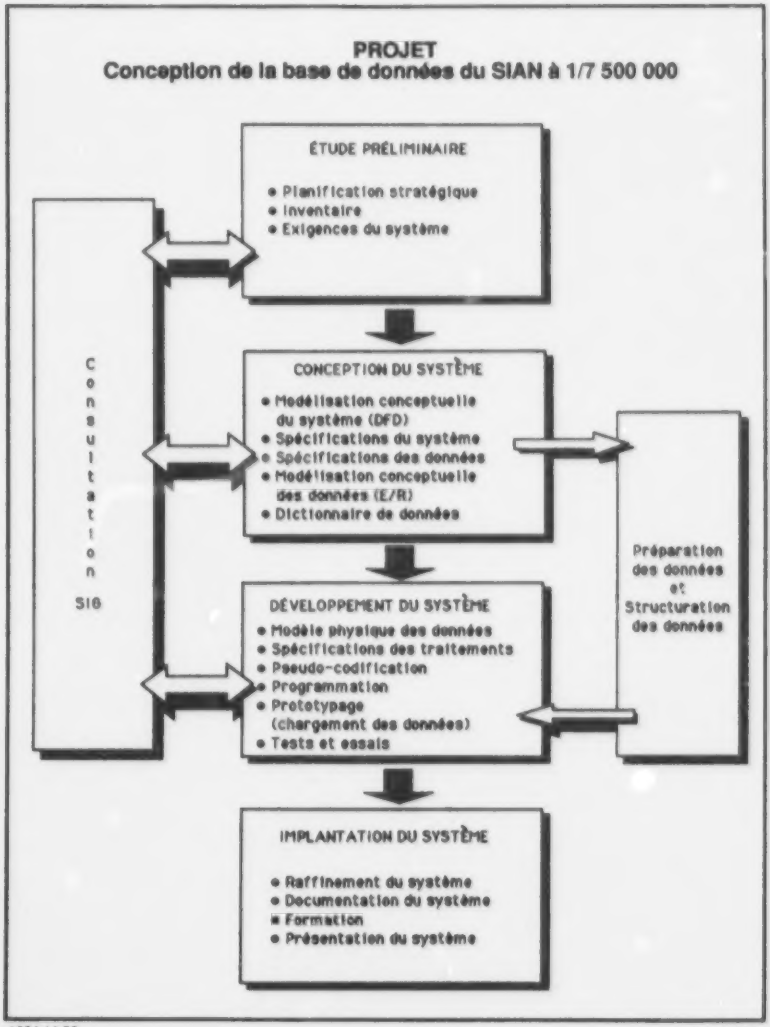
Pour mieux cerner l'information disponible, différents paramètres clés ont été scrutés : la provenance des données, l'information et le type de données, les échelles de représentation des données, le facteur temporel associé aux données, et finalement les différentes représentations des données.

3.1 Source de données

La cinquième édition de l'*Atlas national du Canada* constitue la principale source d'information utilisée. Commencée en 1978, elle compte actuellement plus de soixante-quinze cartes terminées et imprimées, pour un total prévu d'une centaine de cartes. Certaines cartes ont été produites à forfait par des organismes (établissements d'enseignement ou autres) spécialisés dans le domaine de la géographie. Le SIAN supervise la réalisation de ces cartes, et s'assure que ces organismes respectent les normes géographiques et cartographiques établies par le SIAN. Les autres cartes ont été réalisées directement par le personnel du SIAN. Les différentes sources utilisées, parfois assez nombreuses, sont indiquées sur chaque carte.

Une autre source de données est la Base de données toponymiques du Canada (BDTC). Celle-ci est une base de données opérationnelle en place au SIAN. Via un code unique associé à chaque nom, la BDAN pourra avoir directement accès à toutes les informations auxiliaires attachées à chaque nom contenu dans la BDTC.

Graphique 2


PROJET
Conception de la base de données du SIAN à 1/7 500 000
ÉTUDE PRÉLIMINAIRE
• Planification stratégique
• Inventaire
• Exigences du système
CONCEPTION DU SYSTÈME
• Modélisation conceptuelle du système (DFD)
• Spécifications du système
• Spécifications des données
• Modélisation conceptuelle des données (E/R)
• Dictionnaire de données
DÉVELOPPEMENT DU SYSTÈME
• Modèle physique des données
• Spécifications des traitements
• Pseudo-codification
• Programmation
• Prototypage (chargement des données)
• Tests et essais
IMPLANTATION DU SYSTÈME
• Raffinement du système
• Documentation du système
• Formation
• Présentation du système
Consultation SIG
Préparation des données et Structuration des données
1991.11.20
SIAN (GGDB)

3.2 Information et types de données

L'*Atlas national du Canada* contient une gamme d'information très diversifiée ayant trait à la géographie physique, politique, culturelle et économique. Il existe 44 domaines d'intérêts plus spécifiques, allant de la géologie et la climatologie au multiculturalisme et à la structure d'âge de la population canadienne. Toutes ces informations regroupent deux types de données, à savoir des données spatiales (graphiques) et alphanumériques (attributs).

Les données spatiales sont composées d'entités ponctuelles, linéaires et surfaciques.

Les entités ponctuelles sont très diverses, puisqu'elles servent à représenter une multitude de phénomèmes, certains plus topographiques (par exemple : ville, aéroport et station de télécommunication) d'autres plus thématiques (par exemple : population active, inventaire forestier et métaux). La symbologie utilisée est généralement beaucoup plus complexe pour la représentation de données thématiques. Elle peut varier selon la forme du symbole utilisé, sa grosseur, les couleurs utilisées et leurs nombres.

Les entités linéaires sont aussi très variées. Au niveau topographique, elles servent à représenter, par exemple, les cours d'eau simple ou les réseaux routiers. Au niveau thématique, on les utilise, par exemple, pour représenter des failles et des lieux de contact sur les cartes géologiques, des routes d'exploration sur les cartes historiques, et des lignes de transmission sur les cartes de communication. De plus, certaines entités linéaires servent à délimiter des entités de surface; c'est notamment le cas pour les provinces et les territoires qui sont bornés par des frontières et limites politiques, et par le littoral canadien (incluant les îles).

Les entités surfaciques sont évidemment très nombreuses en cartographie thématique. Au niveau topographique, des surfaces sont utilisées pour représenter des éléments tels que les surfaces d'eau et le relief. Par exemple, celui-ci, est représenté par des courbes de niveau à des altitudes précises qui décrivent également des surfaces topographiques ayant des équidistances (écarts d'altitude) connues. Le nombre d'éléments thématiques utilisant les surfaces comme forme de représentation est très grand. À titre d'exemple, pensons aux zones de précipitations, aux zones de végétation, aux précipitations saisonnières, aux régions géostatistiques et aux types d'exploitation agricole.

Les données alphanumériques associées à une carte se retrouvent principalement sur la légende, les tableaux explicatifs et les différents textes, tels les notes explicatives en marge de la carte. Les annotations sur la carte, telles les noms de rivière, de lac, de ville, de baie ou de cap font aussi partie des données alphanumériques. Les données alphanumériques décrivent le contenu de la carte et qualifient les données spatiales.

3.3 Échelles des données

Les cartes de l'*Atlas national du Canada* illustrent des phénomènes géographiques se rapportant à l'ensemble du territoire canadien. L'étendue spatiale du Canada constitue une problématique majeure lorsqu'il faut cartographier ces phénomènes (particulièrement les thèmes sociaux). La distribution de la population n'est pas uniforme. Elle est concentrée dans sa partie sud du territoire. Pour complexifier encore plus la modélisation, une douzaine d'échelles différentes ont été utilisées pour cartographier le Canada. L'utilisation de différentes échelles est directement liée à l'information qu'il faut représenter sur une carte.

La densité et la localisation de la population dans un territoire restreint (malgré l'immensité du territoire) exige l'utilisation de différentes échelles et d'agrandissements.

La grande majorité des cartes sont à 1/7 500 000. Cette échelle de base a été choisie afin de bien représenter les différents phénomènes spatiaux pour l'ensemble du territoire canadien. D'un coup d'oeil, l'utilisateur d'une de ces cartes obtient un aperçu complet du phénomène, et ce pour le Canada en entier. En fonction de la thématique représentée, l'information peut être minimale (ou inexistante) dans certaines parties du pays. Mais n'oublions pas que l'absence d'information c'est aussi de l'information.

Certains sujets, ne pouvant être représentés sur une seule carte, ont été décomposés en une série de cartes à des échelles réduites; c'est le cas pour certaines données climatiques (températures, rayonnement solaire). D'autres, en plus de contenir une carte de base, possèdent un ou plusieurs agrandissements pour les zones où l'information est trop dense. À titre d'exemple, les régions géostatistiques (divisions et subdivisions de recensement) sont représentées, sur une même feuille, à l'échelle de 1/7 500 000 pour l'ensemble du pays et à 1/2 000 000 pour le corridor Windsor-Québec.

3.4 Aspect temporel des données

L'aspect temporel peut également jouer un rôle important lors de la modélisation des données. Voudra-t-on un jour intégrer les données provenant des éditions antérieures? Comment modéliser les données de la cinquième édition de l'Atlas national qui ont été produites sur une période de plus de dix ans?

Selon les cartes, l'échelle temporelle du phénomène représenté varie énormément; certaines cartes représentent des phénomènes s'étalant sur des centaines d'années (cartes historiques tel que l'évolution territoriale du Canada qui reflète l'historique des frontières du pays, des limites provinciales et territoriales du 1er juillet 1867 à aujourd'hui) alors que d'autres peuvent s'étaler sur une saison mais représenter un phénomène répétitif. De nombreux exemples sont connus: les données climatiques (rayonnement solaire, précipitations, etc.) varient en fonction des saisons, des mois, des jours et des heures. D'autres cartes représentent une image dans le temps puisqu'elles ont été produites à partir de données collectées sur une période définie. Par exemple, les données de base servant à la production d'une carte peuvent provenir des données du recensement canadien; dans ce cas, la collecte se fait en une journée.

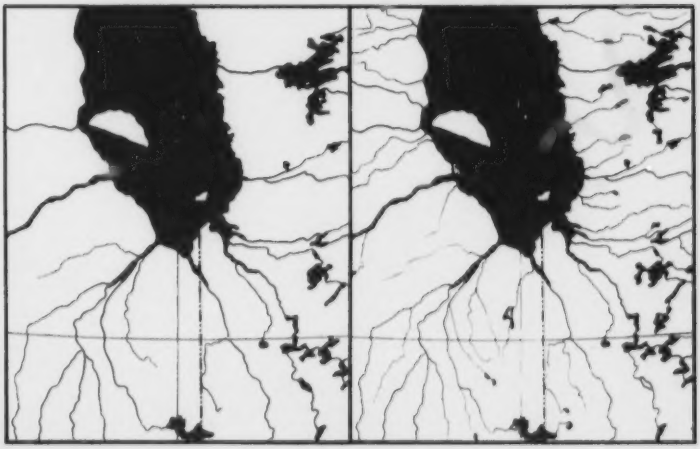
De plus, il arrive que des cartes, incorporant des informations similaires, utilisent des sources de dates différentes. Par exemple, l'information sur les lieux habités peut provenir de compilations de 1978 ou 1981. Un choix doit donc être fait et celui-ci ne peut être basé uniquement sur la date, puisque la compilation peut varier selon les besoins de la carte.

3.5 Représentation multiple des données

Le même type d'information contenue sur différentes cartes peut être représentée de façons différentes. À titre d'exemple, pour certaines cartes de l'atlas, l'hydrographie, les lieux habités et les noms géographiques (toponymie) peuvent être cartographiés à des densités différentes: faible, moyenne ou dense. La même information peut également avoir différentes provenances et représentations; c'est le cas pour les routes et les chemins de fer. Le graphique 3 illustre deux des différentes densités d'information. Il est également possible qu'une entité soit représentée différemment selon l'échelle, la thématique ou la densité d'information.

Graphique 3

Hydrographie médium **Hydrographie dense**



4. Décisions affectant la modélisation des données

Au début du projet, durant la phase de planification stratégique, plusieurs décisions ont été prises conjointement par les gestionnaires et les membres de l'équipe de projet, concernant la conception de la BDAN. Certaines d'entre elles identifient la provenance des données et le contenu de la base de données; d'autres définissent globalement la structure et les relations entre les données. Voici, à titre d'exemple, certaines des décisions se rapportant à la modélisation des données :

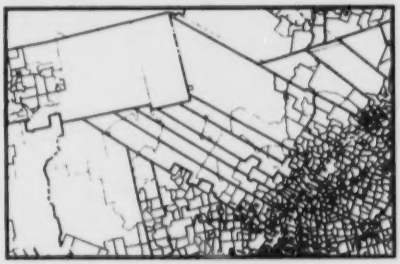
- Les données sont collectées sur une base de composante spatiale. Une composante est un élément spatial (point, ligne ou surface) qui représente un phénomène géographique particulier. Il est donc possible qu'une carte représente plusieurs composantes spatiales mais que seulement l'une d'elles soit incorporée dans la BDAN. Par exemple, la carte du réseau de transport ferroviaire qui comporte différentes composantes spatiales (hydrographie, lieux habités, région démographique, tunnels ferroviaires et réseau ferroviaire), pourrait être utilisée pour extraire les tunnels et les lignes du réseau ferroviaire seulement.

- Autant que possible, les attributs seront extraits directement des informations disponibles sur les cartes de l'Atlas. Des cartes et des données auxiliaires provenant d'autres sources pourront aussi être utilisées lorsque jugées appropriées. Le matériel (cartes) d'autres organismes devra cependant être ajusté à celui de la BDAN. Dans la mesure du possible, des liens seront conservés avec des bases de données externes via des codes d'identification uniques. Par exemple, les codes uniques des divisions de recensement nous permettent d'associer à ces surfaces une multitude d'informations disponibles de Statistique Canada.

- La densité de l'information correspondra généralement à ce qu'on retrouve à l'échelle de 1/7 500 000. Par contre, il ne faut pas oublier que dans un environnement numérique, l'échelle n'est qu'une abstraction donnant une idée de la densité souhaitable d'information. Il est donc possible de représenter, dans une base de données, des éléments qu'il serait impossible de représenter sur une carte à une échelle de1/7,5 million. Nous entendons profiter de cette possibilité pour représenter certaines entités. Pensons ici aux subdivisions de recensement en région urbaine. À l'échelle de 1/7 500 000, il est impossible, dans la région de Montréal, de discerner quoi que ce soit (voir le graphique 4). Nous conserverons donc l'information disponible à une échelle plus adéquate, soit le 1/2 million et celle-ci sera intégrée aux autres informations.

Graphique 4

Divisions et subdivisions de recensement



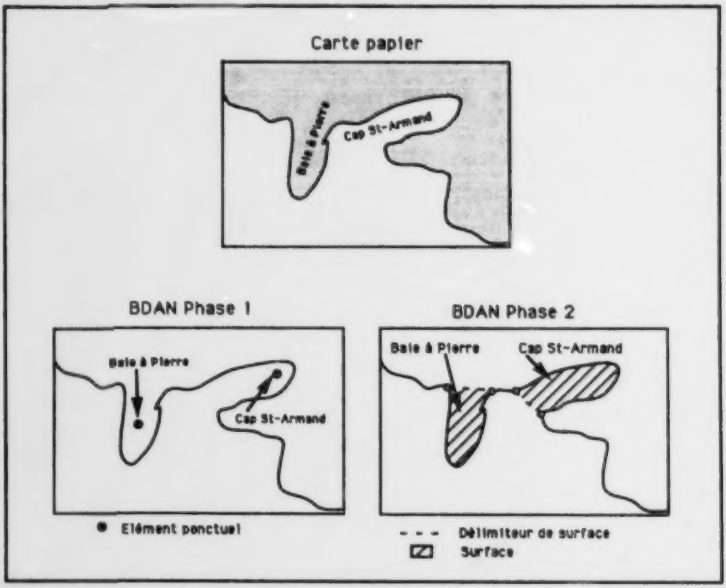
- La base de données ne contiendra, dans un premier temps, que des données vectorielles. Toute source d'information différente devra être vectorisée avant d'être intégrée à la BDAN.

- La BDAN contiendra des composantes spatiales de base et des composantes spatiales thématiques. Les composantes de bases seront structurées topologiquement entre elles. Les composantes thématiques ne seront pas stucturées topologiquement les unes avec les autres. Elles doivent cependant s'ajuster graphiquement (superposition parfaite) avec le littoral canadien, les îles et la frontière canadienne.

- Certaines données spatiales auront en attribut leur nom. Selon la source utilisée, il sera plus ou moins facile d'obtenir toute l'information spatiale attachée à un nom. Dans le cas des rivières et des lacs, il sera possible d'obtenir toutes les informations spatiales se rattachant à un nom. D'autres éléments ne sont représentés spatialement que par un point puisqu'elles proviennent de la couche cartographique des noms géographiques (annotations). Ces points se retrouvent généralement au centre de l'élément mais ne peuvent représenter l'entité au complet. C'est le cas pour les baies, les détroits, les caps, les pointes et beaucoup d'autres entités. On doit mentionner en plus que ce ne sont pas tous les éléments représentés qui sont nommés. Par exemple, l'espace disponible sur une carte ainsi que l'esthétique cartographique ne permettent pas de nommer toutes les baies alors qu'il est très facile de le faire dans un environnement numérique. Dans une deuxième phase de mise en place de la BDAN, toutes ces entités géographiques seront, dans la mesure du possible, délimitées spatialement et nommées. Le graphique 5 illustre les deux phases de mise en oeuvre de la BDAN.

Graphique 5

Phases de mise en oeuvre pour les noms (annotations) de la BDAN



Il est à noter que les noms géographiques doivent respecter l'appellation officielle telle que définie par le Comité permanent canadien des noms géographiques (CPCNG).

- À plus long terme, le plan est de peupler la BDAN avec des attributs supplémentaires à ceux disponibles directement dans l'Atlas national. Ce choix se fera en fonction des besoins des géographes du SIAN et des utilisateurs externes.

Afin d'accélérer le processus de mise en place de la BDAN, et considérant la quantité de données spatiales et alphanumériques que contient l'Atlas, il a été décidé que, dans un premier temps, seulement une partie de cette information serait modélisée. Le contenu sera achevé ultérieurement. Le contenu initial de la base de données a été identifié par le groupe des géographes durant la phase de définition des exigences du système. À titre d'exemple, le tableau 1 indique les différentes composantes spatiales sélectionnées, et certains des attributs qui leur sont associés.

Tableau 1

CONTENU INITIAL DE LA BDAN [1]
(composantes spatiales et attributs)

Composantes spatiales	Type[2]	Attributs
Cercle Arctique	B	Latitude
Chemins de fer	B	Classification Statut Propriétaire/Locataire Volume de transport
Cours d'eau	B	Nom Bassin de drainage Longueur Code BDTC[3] Débit annuel moyen Débit maximal moyen Débit minimal moyen Code densité
Divisions de recensement	B	Nom Code SC[4] Population Superficie
Écoumène (Région démographique)	T	Densité de la population
Espèces en voie d'extinction[5]	T	Nom du groupe Noms des espèces Désignation Date Écodistrict Richesse de l'espèce Facteur de risque
Îles	B	Nom Province/Territoire Code BDTC Superficie Code densité
Frontières et limites politiques	B	Classification Régions impliquées
Glace de mer[5]	T	Type Fréquence d'occurence
Glaciers	T	Type
Lacs	B	Nom Bassin de drainage Code BDTC[3] Périmètre Superficie Code densité

Composantes spatiales	Type[2]	Attributs
Lieux habités	B	Nom Classification Population Code BDTC[3] Code SC[4] Code densité
Littoral	B	Province/Territoire
Parcs nationaux	T	Nom Classification Date de création
Projection	B	Latitude/Longitude
Région habitées (AR[6], RMR[7])	B	Nom Classification Population Superficie
Relief/Bathymétrie	T	Élévation/Profondeur
Réserves indiennes	B	Nom Bande Population Superficie
Routes	B	Nom Numéro Classification Nombre de voies Type de surface Volume de transport
Sites Protégés	T	Nom Classification Catégorie UICN[8] Date de création Superficie Niveau responsabilité Agence responsable
Subdivisions de recensement	B	Nom Code SC[4] Population Superficie
Autres composantes[9] (Baies, caps, etc.)	B	Classification Nom Code densité

Notes: 1 En date du 30 décembre 1991
2 B = Base, T = Thématique
3 Base de données toponymique du Canada
4 Statistique Canada
5 Données pas encore disponibles (sorte en préparation)
6 Agglomération de recensement
7 Région métropolitaine de recensement
8 Union internationale de conservation de la nature
9 Composantes spatiales représentées par un point (localisation approximative au milieu de l'entité)

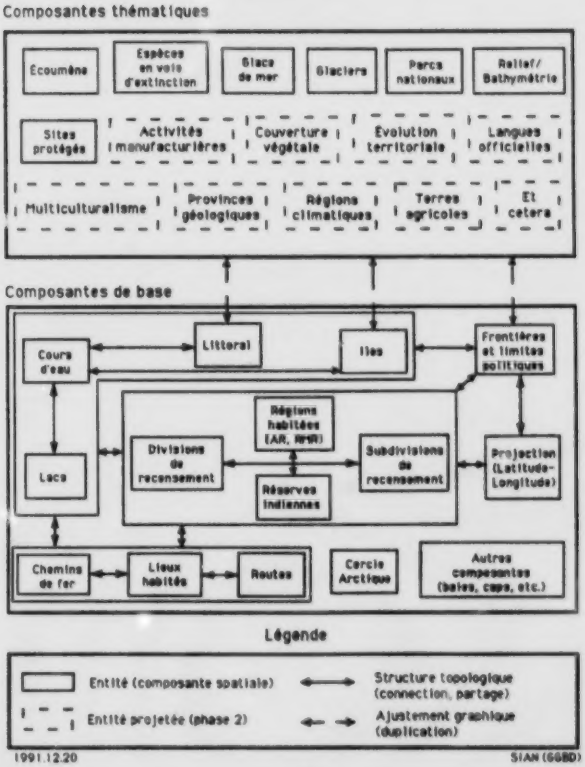
5. Modèle conceptuel des données

Différents niveaux de modélisation (conceptuel, logique et physique) sont successivement utilisés lors de la conception d'une base de données. La modélisation conceptuelle est présentée dans cette section du texte. Ce niveau de modélisation donne une vision générale de l'organisation des données.

Cette modélisation est une étape importante dans l'élaboration de ce projet. Le modèle résultant se doit d'être flexible afin de permettre l'expansion et la mise à jour efficace de la BDAN. Le graphique 6 illustre les différentes entités sélectionnées et les relations existant entre elles.

Graphique 6

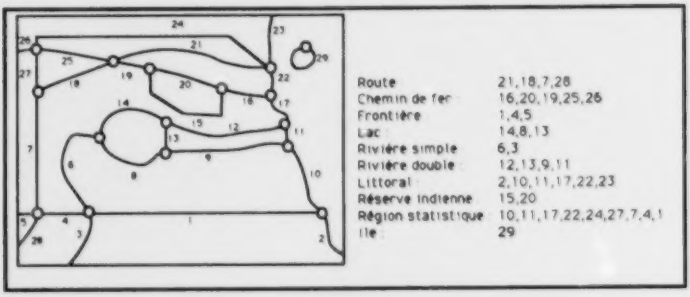
MODÈLE CONCEPTUEL
BASE DE DONNÉES DE L'ATLAS NATIONAL
1/7 500 000



Les composantes de base sont en relation, entre elles, suivant une structure topologique précise (connection et partage) (voir graphique 7), tandis que les composantes thématiques s'ajustent graphiquement (superposition parfaite, duplication) avec le littoral, les îles, les frontières et limites politiques (voir graphique 8). Il n'existe aucune relation explicite entre les composantes thématiques sinon, dans plusieurs cas, le partage des lignes de littoral, les îles et certaines frontières internationales.

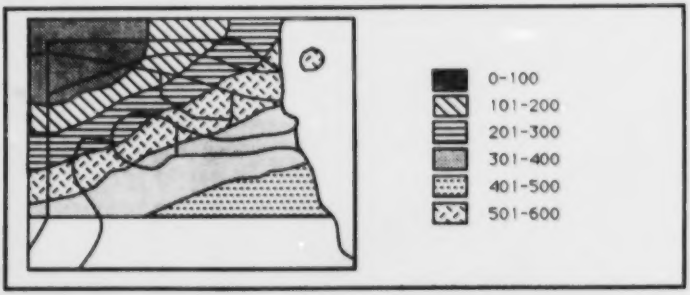
Graphique 7

Structure topologique des composantes de base



Graphique 8

Ajustement graphique des composantes thématiques



6. Conclusion

Lors de la rédaction de ce texte, beaucoup restait à faire dans ce projet et nous nous sommes limités à présenter une partie du travail accompli. Nous espérons lors de la conférence montrer l'état d'avancement du projet depuis cette date. Le but du présent texte était de donner une idée de la complexité de la tâche compte tenu de la diversité des données. Nous espérons que ce texte a suscité votre intérêt et nous serons très heureux, en tout temps, de répondre à vos questions.

7. Remerciements

Les auteurs tiennent à remercier Lise-Aurore Lapalme-Roy et Diane Blondin pour avoir participé à la révision de cet article. Nous tenons également à remercier Patrick Lloyd et Peter Paul pour leur contribution dans le cadre de ce projet.

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A COMPARISION OF MANUAL AND SEMI-AUTOMATIC LINE DIGITIZING

Y.C. Lee and Albert Chow

This paper reports an experiment conducted to investigate the performance of a semi-automated line digitizing system and compare it with traditional manual digitizing. Two maps were digitized first manually on a digitizing table and then on a semi-automated system by an untrained user. The results are compared in terms of completeness, accuracy, and efficiency. They provides insights to the advantages and limitations of both methods of line digitizing.

COMPARAISON ENTRE LES NUMÉRISATIONS DE LIGNES MANUELLE ET SEMI-AUTOMATIQUE

RÉSUMÉ

Cette communication présente les résultats d'une expérience visant à évaluer et à comparer les performances d'un système de numérisation de lignes semi-automatique et de la technique classique de numérisation manuelle. Deux cartes ont été numérisées, d'abord manuellement, à l'aide d'une table numérisante, puis sur système semi-automatique par un utilisateur débutant. Le pouvoir, la précision et l'efficacité de ces deux méthodes de numérisation de lignes ont été comparés. Les résultats contribuent à mettre en lumière leurs avantages et leurs limites.

A BROWSING SYSTEM FOR CARIS ON A NETWORK

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ABSTRACT

This paper reports the development of a low-cost browser for a network GIS. The design of the system is based on CARIS GISs running on different computers over a communications network. The prototype is implemented on an IBM PC-compatible and allows the user to visually overlay several layers of map data within a specified area. The five components of the system, the user interface, the query manager, the data directory, the rule base, and the communications software, will be described.

SYSTÈME DE CONSULTATION RAPIDE POUR CARIS EN RÉSEAU

RÉSUMÉ

Cet article traite de l'élaboration d'un système de consultation bon marché pour un réseau de SIG. La conception du système est basée sur l'exploitation des SIG Caris sur différents ordinateurs dans un réseau de transmission. Le prototype fonctionne sur un PC compatible d'IBM et permet à l'utilisateur de superposer visuellement plusieurs couches de données cartographiques dans une zone particulière. Les cinq éléments du systèmes , l'interface avec l'utilisateur, le gestionnaire des demandes, le répertoire des données, l'ensemble des règles et le logiciel de transmission, seront décrits.

INTRODUCTION

There is a need for efficient data management and data handling in networks connecting users of geographic data. These networks currently support different applications, ranging from personal communication to high-speed network management systems connecting computer systems situated miles apart. A common goal of these applications is to share information and computer resources.

Users of geographic information are concerned with accessing reliable and current geographic information to support planning and decision making and to better manage land resources. At the present time, access to geographic information is sometimes difficult or impossible. Very often, the user must know where the data reside, their quality, who to contact to obtain them, and how to use them. This situation can be improved through land information network management systems which either allow direct access to remote data or provide information on how to acquire them. A review of distributed land information systems is given in Lee and McLaughlin [1991].

A variety of methods have been employed to provide access to distributed geographic data. One such system, described by Star et al. [1987], is the BROWSE system. This system demonstrates a data catalogue system which helps users in selecting data at the host site which is a dedicated database node in a distributed database system. A second approach utilizes Hypercard to create an interface to allow users at a Macintosh workstation to perform operations on a remote ARC/INFO GIS [Cowan and Love, 1988]. Yet a third approach was taken to develop the Geographical Browser [Menke et al., 1991]. In this system, view servers respond to requests for schema and data subsets from the host database management system. A user interface at the user site sends simple commands to the view servers to access the schemas, and it allows users to create queries (based on the schemas) to retrieve data from the host databases.

Unlike the systems described above, this browser allows users to preview and download geographic data and related attributes from multiple host sites. Our browser utilizes a global data directory to determine which sites to access. The data directory is considered a higher level system than the detailed catalogue or view server. Our browser also uses a rule base to translate system-independent commands to system-specific GIS commands.

This project was undertaken as part of an investigation into the issues concerning data management in a network of geographic information systems. The project involves

developing a prototype to search and access data in network GIS. Using menu-driven software, a user may select features (meaning feature types) of interest within a chosen area for previewing and downloading. The ability to preview selected data is seen as a necessity in GIS networks due to the sheer volume of data that is typically associated with GIS databases. By previewing the data, a user can ensure that the required data has been selected, thus reducing significantly the download time. In addition, previewing allows the user to compile a map from several GIS databases at remote sites.

This system serves to demonstrate the following aspects of distributed GIS networks:

- Data directory structure.
- Rule-based remote data access methods.
- Distributed query management.

A key feature of the system is the use of low-cost software and hardware. It incorporates custom software, public domain terminal emulation/file transfer software, and a low-cost relational database management system on an IBM PC-compatible computer. Even with low-cost components the system provides data access and on-screen map compilation over a GIS network environment. The present design is customized for CARIS running on different operating systems and computers. CARIS (Computer Aided Resources Information System) was developed by Universal Systems Ltd. in Fredericton, N.B. The version used in the project reside on a VAX VMS. We will outline in this paper how the design can be enhanced to support other GISs.

The browsing system was implemented on a 80206-based IBM PC-compatible computer. The computer has 640K of RAM, no math coprocessor and featured a Hercules-compatible graphics card. Despite the low-end hardware used, the system was found to function adequately for serial line communications with the remote GIS at 9600 baud.

BROWSING SYSTEM ARCHITECTURE

The browsing system has five logical components: user interface, query manager, data directory, communications software, and rule base (Figure 1). The user interface is menu driven, and it allows the user to select the area and layers of information to be viewed. The query manager coordinates the user interface with the other components to access the remote GIS and to download data. The data directory describes the distribution

of data over the network. The rule base is used to create commands for data access. Both the data directory and the rule base are implemented as tables in a relational database management system, and embedded SQL statements are used to interface the query manager with the data directory and the rule base. The communications software emulates a Tektronix terminal and transfers data across the network. The following sections describe the components in more detail.

The User Interface

The user interface provides the user with menus to guide through the viewing or accessing of data. The routines are written in the C language. Through the interface, the user selects features within a chosen area and then may view or download the selected spatial data, list the attributes of a feature with a given feature identifier, or download all of the attributes of a feature type within the specified area.

When selecting features, the user is presented with a list of available features and a list of any previously chosen features. The user is then given the option to add or delete features from the list, clear the list, or select all features.

When selecting an area, the user is given the option of entering a map sheet number, choosing a map from an index of available map sheets, or entering the township, range, and meridian identifiers of the map sheet desired.

When selecting the attributes of a particular feature, the user is asked for the particular feature type to be queried and the feature identifier of the individual feature to be listed.

The Query Manager

The query manager is a set of routines, written in the C language, which interpret and control the processing of user requests. Requests passed from the user interface are matched with a finite set of available commands and the appropriate operations are carried out.

The query manager interacts with the data directory to get feature names during the feature selection process. The user interface initiates this with a "get features" command, and this results in a list of selected feature types stored for future reference. The query

manager also accesses the data directory to get the location of remote data and communication parameters necessary for remote system access.

Interaction with the rule base takes place when a request for data access or data browsing occurs. The query manager finds the appropriate rules from the rule base and uses them to set up a command file that the communications software executes to perform remote operations. The query manager invokes the communications software to perform remote operations after setting up the command file.

The Data Directory

The data directory is a set of relational database tables which give the location of network data and provide details about accessing the remote data. The browsing system was developed with the PACEBase database management system which has a development version including a C language interface [Graham et al., 1989]. The tables used in the data directory for this project are: theme, remotetheme, location, area, and att_table. They are described below.

The browsing system groups features into themes. The "theme" table provides the names of available features and gives descriptions of those features which are used during feature selection. The theme table is as follows. The field name(s) in italic forms part of the key.

TABLE:	theme	
FIELDS:	*theme*	the browse system feature theme
	description	the description of the feature theme

Data for a theme at the browser's set might be distributed over the network. The table "remotetheme" relates the browser's feature themes and the themes in the remote systems. The remotetheme table is as follows:

TABLE	remotetheme	
FIELDS	*theme*	the browse system feature theme
	remotetheme	the remote system feature theme
	description	the description of the remote theme
	owner	the name of the owner
	location	an identifier for the remote system
	database	the name of the remote spatial database
	attr_db	the name of the remote attribute database
	theme_ident	a feature identifier for the remote theme
	starting_task	the first task to set up in the command file

The table "location" is used to provide the basic communication parameters for remote access. The table is as follows:

TABLE:	location	
FIELDS	*location*	the name or address of the remote system
	logonid	an encrypted logon identifier for system access
	passwd	an encrypted password for system access
	port	the communications port to which the remote system is connected
	baud	the baud rate for communication
	parity	the parity setting for communication
	protocol	the handshaking protocol used
	duplex	full or half duplex communications

The table "area" is used to identify the database in which each map sheet can be found. A record is reserved for each map sheet in each database. For the map sheets used in this project, the map sheet boundaries also correspond to Dominion Land Survey System township boundaries. Therefore, township identifiers are also used in the area records. The table is as follows:

TABLE:	area	
FIELDS	*location*	the name or address of the remote system
	database	the name of the remote spatial database
	mapsheet	the map sheet identifier
	twp	the township identifier
	range	the range identifier
	merid	the meridian identifier

The table "attr_table" provides the data necessary to access the attribute table of the remote databases. The table is as follows:

TABLE:	attr_table	
FIELDS:	*attr_db*	the name of the attribute database
	theme	the name of the feature theme to which the attributes relate
	attr_table	the name of the table in the remote database which contains the attributes
	pid_name	the name of the field in the attribute table which contains the identifier of the feature

The tables given above provides all of the data necessary to allow data access in the prototype system. In a heterogeneous network it may be necessary to indicate what GIS is used at each location.

The Communications System

A public domain terminal emulation and file transfer program called Kermit was used for the communications system. Kermit is a widely used program. Versions of the software exist for many operating system and hardware combinations, including the MS-DOS IBM PC and VMS VAX systems used in this project [Gianone et al., 1988].

Kermit also refers to the file transfer protocol used by the Kermit software. The Kermit protocol was developed at Columbia University in 1981 [Anderson, 1989]. This protocol is often implemented in public domain and commercial communications systems.

The version of Kermit used in the browsing system project was written, in Pascal, at Queen's University in Ontario. This version features Tektronix graphics terminal emulation and can be executed in batch mode through a command file, called a "task file" in Kermit terminology. Commands used in Kermit vary slightly between implementations but typically include the following:

SET	to set communication or Kermit parameters.
SEND	to send a file or files to another Kermit at a remote system.
RECEIVE	to receive a file or files from another Kermit at a remote system
CONNECT	to switch to terminal emulation mode.
OUTPUT	to send a string to the communication line.
INPUT	to read a string from the communication line.

A number of changes were made to Kermit for this project in order to match its operation with the needs of the browsing system. Among the modifications were:

- Improved output of printable ASCII characters in Tektronix emulation mode.
- Streamlining of the input command operation to minimum processing.
- Removal of Kermit messages (in favour of user-generated messages in the take file).
- Addition of support for outputting control characters from take string output command parameters.

- Addition of a CONNECT UNTIL command option for the connect command which "switches off" terminal emulation mode when a specified parameter string is received by the emulator.
- Addition of graphic screen saving until a refresh command is received. This allows switching between the text screen and graphics screen without losing graphics displays.
- A number of minor bug fixes and enhancements to support the GIS software used in the project.

The Rule Base

The rule base contains information necessary to create command files to control operation of the communication system during data access and browsing. The rules are used to translate a system-independent "task" into a series of system-specific "steps". An example of a task is CONNECT which establishes connection between the browser and the host GIS. The first step in this task is to send the SET PORT NET command to Kermit.

There are two kinds of rules. The first type are remote rules used to directly create commands for Kermit. Some of these commands control Kermit, some of them request Kermit to output a command string to the host system, and some of them request Kermit to input data or messages from the host system. The input and output commands together support interactive dialogue between the browser and the host GIS. A particular task, such as CONNECT, might require several rules to define. In the rule base, these rules are chained together. Hence processing of a task in this case involves locating the start of the chain, linking the related rules together, and converting them to Kermit commands one by one.

The rules are stored in tables in a relational database, and a portion of the table is shown below. Field names in italic form the key.

location	*task*	*task_step*	action	next_step
VAX01	CONNECT	START	SET PORT NET	STEP=CONNECT_2
VAX01	CONNECT	CONNECT_2	...	

The "location" field identifies the system to which the rule applies. In this case, the rule applies to one of several VAX computers. The "task" field contains the name of the browser task which is to be performed. The field "task_step" contains the name of a step in this task. The special values "START" and "END" are used to identify the beginning and end of each task. The "action" field gives the Kermit command to be performed. The "next_step" field is used to link the steps together. In this case, it shows that the next step of the CONNECT task is called CONNECT_2. The second rule, having a task_step of CONNECT_2, is the continuation. Sometimes a task contains two or more smaller tasks. In this case, the "next_step" field can also be used to link subtasks together.

The remote rules are useful in describing tasks consisting of a fixed chain of steps or subtasks. Sometimes a task consists of a *set* of subtasks to be determined at run time. The second type of rules, called local rules, can be used to handle this situation. For example, the rule base might contain several tasks, each describing how to select a particular feature type to be displayed. Hence the task LOT could generate commands to the host GIS to display land parcels, and the task ROAD could generate commands to display roads. In the rule base, the task SELECTIVE_DISPLAY which displays selected layers of data is implemented as a local rule so that the user can control the correct combination of features each handled by a subtask. The rule for this task is

location	*task*	*task_step*	action	...
LOCAL	SELECTIVE_DISPLAY	START	LOOP WITH TASK=$FEATURE	

The "action" field indicates that the SELECTIVE_DISPLAY task is composed of a set of subtasks which names are supplied in a separate file created by the browser after asking the user to select features for display. If the features selected are LOT and ROAD, then $FEATURE will be substituted with the appropriate feature type and the LOT and ROAD tasks will be invoked to ask the host GIS to select land parcels and roads for display.

USING THE BROWSING SYSTEM

To use the browsing system a user must select features of interest, select an area, and choose a remote operation to be performed. When the user first chooses to select features, the user interface sends a "get features" command to the query manager. The query manager then retrieves all features from the data directory and stores them in a linked list. When a feature is selected by the user a flag is set to indicate that the feature was

chosen. The collection of features in the linked list with the feature-chosen flags set form the list of selected features. This linked list and the feature-chosen flags remain in memory until the system is terminated.

When a user chooses to select an area, the user is given the option of supplying a map sheet number, entering the township range and meridian identifiers, or choosing the map sheet number from an index map on the terminal. The index used in the prototype is simply a small grid which shows the location of the City of Regina for reference. The map sheet number of the available map sheets are shown in the appropriate grid cells.

When a user chooses to view or download data the user interface sends the query manager a command to perform the selected operation. Feature names and the selected area are passed to the query manager as environment variables. The query manager then obtains the location of the data and the communication parameters from the data directory and starts building the command file, utilizing rules from the rule base. When the command file has been built the query manager executes Kermit.

FUTURE DEVELOPMENTS

To date the browsing system has been tested with one remote GIS. Each of the operations has been successfully tested. Future developments planned include enhancing the system to function on a TCP/IP Ethernet network and adding the ability to concurrently access two separate GIS databases. A screen overlay feature will be added to support concurrent access.

The second GIS added will be a UNIX CARIS on a SUN workstation. The addition of a third hardware platform and operating system will illustrate heterogeneous communications.

CONCLUSIONS

We have described the design of a browsing system which can access CARIS GISs residing on different computers using different operating systems over a network. A prototype was written in C for an IBM PC compatible, and it was tested using a single CARIS site on a VAX computer. An important feature of this browser is the previewing of geographic data from different sites, thereby allowing the creation of visual overlays on the browser's terminal from data scattered over the network.

The system is based on a modified Kermit functioning as a Tektronix 4010 emulator and file transfer software. This provides a very cost effective, although not highly efficient, method of accessing a remote CARIS. The communications software is supported by other modules to handle queries and access data over a network. The core module is the query manager which obtains the query through the user interface, consults the data directory to determine the location of data, uses the rule base to translate user requests to system-specific commands, and accesses a remote GIS through Kermit.

Both the data directory and the rule base were implemented as tables in a relational database management system. This design allows the easy customization of the browser to access CARIS on different computers and operating systems. The project points to the possibility of developing a browser of heterogeneous GISs.

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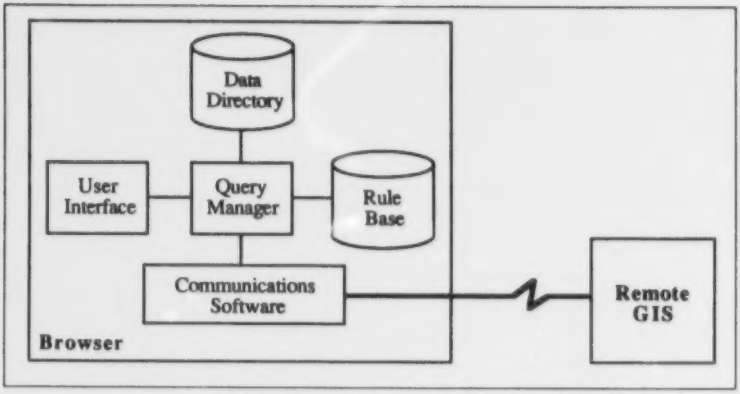

Figure 1: Architecture of the Network Browser

THE SURVEYING CURRICULUM AND THE CHALLENGES OF GIS

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ABSTRACT

The world today is witnessing tremendous technological developments which are taking place at a frighteningly rapid pace. We are living in a world which is increasingly becoming independent on information and in which the volume of information is increasing exponentially. The demand for the routine technical and manipulative skills of the surveyor is increasingly diminishing. The current emphasis is upon the linkages between spatially distributed attributes and dynamic change.

It is therefore needless to say that one of the consequences of this exponential growth in the quantity of information and the complimentary development in the technology of information gathering and management is that we should take a hard look at our surveying curriculum and think towards liberalizing surveying education to enhance its adaptability to change in focus.

The curriculum proposed in this paper would therefore in addition to ensuring that surveyors are being educated and trained in such a way that they possess the necesary competence to perform surveys also ensure the following:

(a) That the surveyor is able to manage a multi-disciplinary land development project.

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(b) That the surveyor is able to to adapt to changing legislative programmes and social needs.

(c) That the surveyor is able to play a leading role in a multi-disciplinary environment like GIS.

(d) That the surveyor is able to expand his horizon and consequently his opportunities for serving the society.

LES PROGRAMMES D'ÉTUDE EN ARPENTAGE ET LE DÉFI DES SIG

RÉSUMÉ

Nous vivons à une époque où la technologie fait d'énormes progrès et évolue à une vitesse vertigineuse. Aussi, nous dépendons de plus en plus d'une multitude d'informations, qui s'accroissent exponentiellement. Les compétences techniques classiques des arpenteurs sont de moins en moins en demande. On met maintenant plutôt l'accent sur les liens entre la distribution spatiale des attributs et le changement dynamique.

Inutile de dire que cette croissance exponentielle de la quantité d'informations et les progrès concomitants des technologies de collecte et de gestion de l'information ont notamment pour conséquence que nous devons revoir en profondeur les programmes d'études en arpentage et assouplir la formation dans ce domaine de façon à ce qu'elle s'adapte au changement.

Cette communication présente un programme d'études qui, en plus de donner aux arpenteurs les compétences théoriques et pratiques nécessaires à la réalisation de levés, leur permettra :

(a) de gérer des projets multidisciplinaires d'aménagement du territoire;

(b) de s'adapter à l'évolution des besoins sociaux et aux modifications apportées aux programmes législatifs ;

(c) de jouer un rôle de premier plan dans le domaine multidisciplinaire des SIG;

(d) d'élargir leurs horizons et, ce faisant, de mieux servir la société.

INTRODUCTION

The education and training of the surveyor has previously tended to concentrate mostly on the technical aspects of the surveying and mapping process. This approach no doubt contradicts the philosophy behind a profession. This philosophy is illustrated in [Hoodsteden, 1986, p.504]

> **When education becomes training, when it is too intensively focussed on specific practical skills, its rate of obscolescence may be disastrous. The surest way in which professions can degrade their status and their ultimate public usefulness is for them to skimp study of their underlying principles in pursuit of illussory immmediate advantage.**

The world is witnessing tremendous technological developments which are taking place at a frightening rapid pace. We are virtually living in an information-dependent society. These changes are putting pressure on the profession for a re-examination of its role today and in the future. It is therefore not surprising that at each surveying forum the future role of the surveyor and his image have always been discussed both formally and informally.

The development of Geographical Information Systems (GIS) has brought together different professionals, each struggling to lead the group. The complexity of the graphics, file management and information disemination germane to a multi-disciplinary system like GIS is further alienating the surveyors to the advantage of the computer scientists. Hence the wrong perception of the surveyor as a mere system user or at best a peripherial contributor to GIS. This is as opposed to his central role in the system development and operation.

There is therefore an urgent need for the surveying curricula to be reviewed in such a way as to balance the surveyor,s technological ability with a better understanding of land management, law, GIS and practical skills. The suggestion at the XIX FIG congress of the need for greater reliance on the 'survey technologist' as the technical 'expert' and a greater emphasis on the 'professional surveyor' as integrator of technology and information is recognised in this paper.

The surveying curriculum suggested in this paper addresses the need for flexibility and proper focus necessary for keeping pace with the rapidly changing technology with a view to being consistent with the services required by the society.

INCORPORATING GIS INTO THE SURVEYING CURRICULUM

The development of GIS and GPS technology is posing a great challenge to surveying and mapping institutions. Information about land and its resources have been recorded and used for planning and policy making since antiquity. The need for timely and and accurate information about land is becoming increasingly recognized. Man's population is increasing daily while the degradation of soils, forests etc continues unabated. GIS/LIS will provide the variety of spatial data needed to construct alternative land models to examine the consequences of various decisions.

A major concern to the profession currently is the continued reduction in both number and quality of people coming into the profession. GIS offers an ample opportunity for us to expand and attract more qualified students into the profession. GIS is fast gaining popularity that the number of people using spatial data is steadily on the increase. This will no doubt call for the services of the surveyor. But to offer services consistent with the demand of this modern techn ology we must expand our horizon while compressing some of the "traditional" core surveying subjects. To do otherwise would mean our profession losing the central role it is expected to play in GIS.

Surveyors of the '90s and beyond must therefore be seen as managers of information and not just information gatherers. Changes in society create pressures for change in the general education process. The future survival of any profession rests on its capacity to adapt to changes. Current surveying curriculum must therefore address the following questions: [Hoodgateden,1986,p.496]

(a) Are surveyors being educated and trained in such a way that they possess the necessary competence to perform surveys?

(b) Are they able to offer wise counsels to clients of various social classes and interests?

(c) Can they adapt to changing legislative programmes and altering social needs?

(d) Are they able to evaluate problems in a critical yet constructive

manner?

GIS as a subject of instruction and research in surveying education is already being practised in Canada, USA, Australia and United Kingdom. The trend has been either to offer specialised programmes in GIS or to incorporate GIS courses in the regular surveying curriculum.

The author prefers the latter. The surveying curricula being run currently in many schools round the globe already have substantial number of courses relevant to GIS. Incorporation of GIS into our regular programme would be in line with the evolution process of surveying education. The benefits of such an approach are very significant.

(a) It will expand the latitude of services offered by the surveyor which will enhance the the recognition of the surveyor.

(b) It will build in the the desired flexibility which will enable the surveying graduates adapt easily to changes in technology and social needs.

(c) It will increase the number of people coming into surveying. An immediate consequence of this is the impact on the quality of surveying graduates who will be better equiped to tackle the challenges posed by the modern society.

THE PROPOSED SURVEYING CURRICULUM

A gaze at the near and distant future suggests an increasing and steady erosion of the traditional skills of the surveyor by technology. Traditional geodetic surveying and position techniques are becoming less popular with the increase application of GPS, fully digital photogrammetry and the integration of cadastres into larger GIS/LIS picture. Remote sensing is fast becoming popular as viable alternative to mapping terrain and even water features in both graphical and digital form using satellites and image processors. The surveyor's duty today and in the distant future extend beyond gathering of spatial data. It includes storing, managing and disseminating spatial information. These views are vividly summerised in [Zwart, 1986, p.33]

In an age where the demand for the routine technical and manipulative skills of the surveyor is diminishing and his ability as a

> technical manager and organizer coming to fore we cannot afford to perpetuate an education that emphasizes the disappearing skills and tend to restrict the acquisition of the tools necessary for survival in the future.

In suggesting an alternative curriculum the multi-disciplinary nature of GIS is recognized and an attempt is made to strike the right balance between "depth," "breadth" and "spread." Depth entails competence in the information that has spatial characteristics, while breadth ensures that surveyors are exposed to other ancillary courses that would enable them evaluate problems critically and be able to adapt to changing legislative programmes and altering social needs. (flexibility). Spread endorses the multi-disciplinary nature of GIS.

The model of the surveying curriculum proposed in this paper is shown in figure 1. The curriculum break-down can be found in appendix I. This curriculum is a five-year standard programme for holders of General Certificate of Education (GCE) Ordinary Level or its equivalent. Holders of relevant Advanced Level Certificates could start in year two with minor adjustments in the programme.

One would easily notice form the curriculum in appendix I that most surveying courses are not given descriptive titles, instead we have surveying I, Photogrammetry I etc. This is intentional. Descriptive titles would not allow the type of flexibility envisaged in this paper. Leaving the nomenclature open will allow for easy modification of the course contents to meet the dynamic changes in technology and information demand. Also this approach would enable the surveying departments to make internal changes within the courses as situations demand without recourse to the rigours of going through the university's curriculum committee who may not understand the urgency and need for the proposed changes.

The place of mathematics and the physical sciences as the foundation of understanding technology is fully recognized in the proposed programme. Mathematics in addition to being a language of precise thought improves one's analytical ability while the sciences enhance the process of systematic enquiry. The study of law develops the mind's capacity for critical and logical analysis and improves one's understanding and compliance with the desired tenets of

one's profession and society at large. To play a leading role in GIS/LIS the surveying curriculum must have sufficient dosage of finance and mangement. The need for this may not be readily obvious. A look at the tasks facing today's surveyor as stated in [Mcgrath,G and Harding, A.G., 1985, p.403] attests to this need.

(a) To understand the changes that are occuring in an increasingly complex and information society.

(b) To determine today's requirements with clarity and precision.

(c) To access how they may be satisfied with the present human and physical resources, and to manage these resources efficiently.

(d) To anticipate future needs for information and define how they should be met.

(e) To consider with care the relative cost competitiveness of his organization's product

(f) To tackle the complexity in financing the costly capital investment programmes proposed for the creation of digital bases as substitutes for relatively static analogue map bases.

The social sciences and humanities explore the collective behaviour of the people while economics in addition provides insight into the rational allocation of resources.

There is no doubt that the introduction of these liberal courses would shrink the large spaces usually allocated to the traditional surveying courses. The aim should be to strike the right balance between technology and liberal education.

CONCLUSION

Information having spatial characteristics have been and remain the prerogative of surveying and mapping. There is currently a growing emphasis upon linkages between spatially distributed attributes and dynamic change. The surveying curriculum must reflect this trend and also possess an in-built flexibility to fit into the violent changes taking place in the information environment.

The model proposed in figure 1 and the accompanying curriculum are in line with the anticipated future demands of the surveying profession. Management, finance, Economics, Law and the social sciences have been given some emphasis in order to expand the horizon of the surveyor and consequently expand his opportunities to serving the society better. To play a leading role in GIS/LIS, courses like database management, computer assisted mapping, land information management, computer graphics and GIS concepts have either been introduced or given more weight.

A major problem with implementing this programme especially in the third world is the dearth of relevant personnel. To this end it will be necessary to retrain staff through linkages with institutions where GIS/LIS has been more developed like in Canada, Australia and United States of America.

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APPENDIX I

PROPOSED CURRICULUM FOR A B.SC. (HONS.) DEGREE IN SURVEYING

FIVE-YEAR STANDARD PROGRAMME

First Year

First Semester	Units	Second Semester	Units
Introduction to Surveying	3	Intro. to Photogrammetry	2
Mathematics I	3	Introduction to Cartography	2
Mathematics II	3	Environmental Studies	3
Physics I	2	Computer Science I	2
Use of Language (eg English)	2	Mathematics III	3
Social Sciences I	2	Use of Language II	2
Physics II	2	Social Sciences II	2
Physics III	2	Practical Physics	2
TOTAL	19		18

Second Year

First Semester	Units	Second Semester	Units
Surveying I	3	Surveying II	4
Photogrammetry I	2	Cartography	3
Computer Science II	3	Electronics and systems	3
Mathematics IV	3	Urban Development PLanning	3

First Semester	Units	Second Semester	Units
Statistics in Measurement	3	Principles of Economics	3
Humanities	2	Physics IV	2
Mathematics V	3		
TOTAL	19		18

Third Year

First Semester		Second semester	
Surveying III	4	Electronic Surveying	3
Computer Applications in Surveying	3	Photogrammetry II	3
Geodesy I	3	Cartography	2
Remote Sensing I	2	Hydraulics for Surveyors	2
Introduction to Adjustment Calculus	3	Map Projection	3
Applied Maths Method in Surveying	3	Land Law	3
		Electives	2
TOTAL	18		18

Fourth Year

First Semester		Second Semester	
Land Economy and Management	2	Professional and Industrial Studies	2
Photogrammetery III	2	Surveying III	3
Hydrographic Surveying I	2	Cadastral Information Systems	2
Advanced Adjustment Calculus	3	Digital Mapping I	2

Cadastre I	3	Hydrographic Surveying II	3
Electives	6	Electives	6
TOTAL	18		18

Fifth Year

First Semester		Second Semester	
Geodesy II	3	Computer Assisted Mapping	2
Photogrammetry IV	2	Urban Surveying and Mapping	2
Survey Laws and Regulations	2	Data Management	2
Land Information Management	3	Digital Mapping II	2
Electives	8	Concept of GIS	2
		Project Report	4
		Electives	4
TOTAL	18		18

Note: Survey camps should be organized during long vacations for the second and third years. The students can then be attached to relevant industries for production experience during the long vacation in their fourth year. Within the semesters, practical/laboratories exercises should be given to the students. Marks scored in these exercises should form part of the final grade.

To graduate a student should return passing grades in both the survey camps and the industrial experience programme.

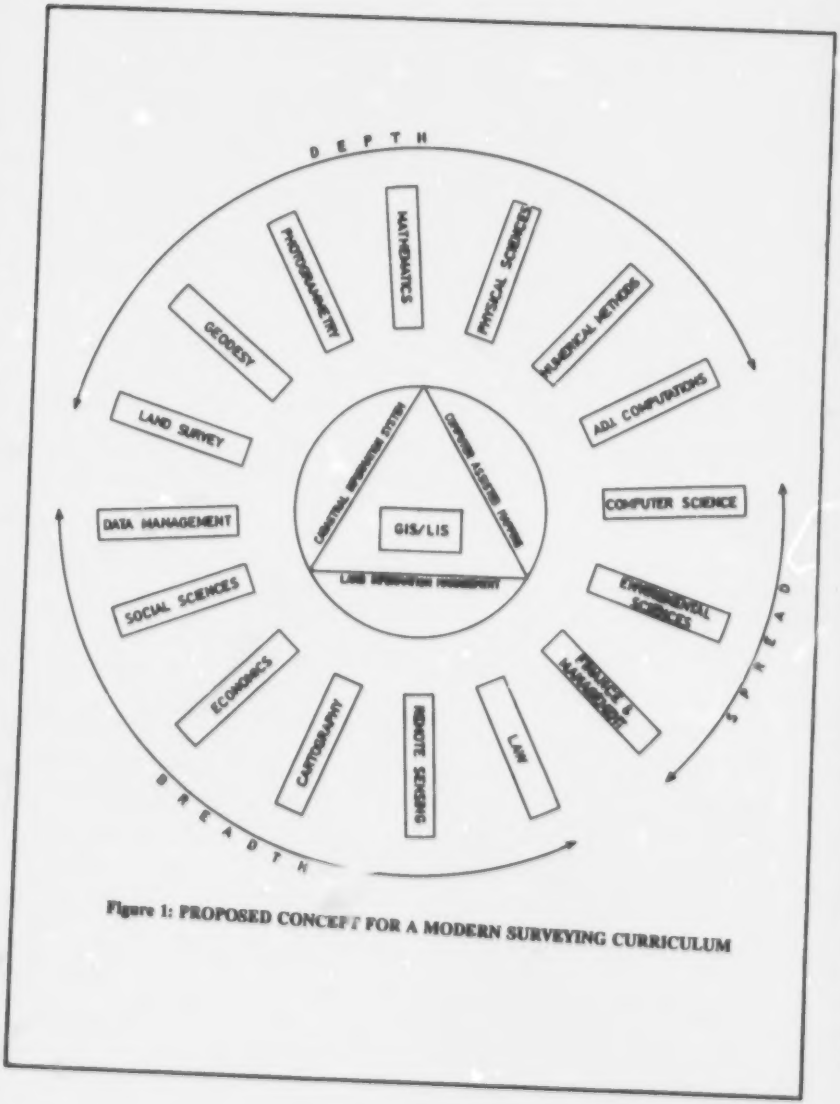

Figure 1: PROPOSED CONCEPT FOR A MODERN SURVEYING CURRICULUM

USING GIS TO MAP SALINITY DEVELOPMENT ON IRRIGATED, AGRICULTURAL SOILS

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Abstract

In the arid, southwestern United States several interacting factors are generally associated with the development of salinity on irrigated lands. Notable examples include physical edaphology (e.g., clay content and soil permability), groundwater conditions and irrigation management. By creating map overlays of these properties and noting the areas of intersection of specific threshold levels or by weighting the significance of each property to the overall salinization process, areas can be delineated that demonstrate varying propensities for salt accumulation in the soil profile.

Initial field studies indicated that the interactions between the salinization factors believed to give rise to salinity development at a study site, the Wellton-Mohawk Irrigation District, were too complex to characterize with a simple threshold level approach. Rather, a means of weighting the significance of the individual factors in the overall salinization process was necessary. Subsequently, a multiple regression model relating soil salinity to various soil salinization factors was developed and used in conjunction with an automated geographic information system, ARC/INFO, to produce a map which accurately delineated areas of low, medium and high salinity.

A multiple regression model was formulated to determine salinization potential from four salinization factors: soil permeability, depth to the groundwater, groundwater quality (i.e., groundwater electrical conductivity) and irrigation efficiency (i.e., leaching fraction). The functional form of the model reflected a

phenomenological basis. The regression model was developed from statistical analysis of soil salinity data for a 170 square-mile study within the Wellton-Mohawk Irrigation District near Yuma, Arizona. Data for the four regressor variables were compiled for the time period 1968-1973. The phenomeological model indicated that salinity development in the top 61 cm (24 inches) of the soil profile was inversely related to the soil permeability and leaching fraction, and directly related to the electrical conductivity of the groundwater, all in a linear manner. A close analysis of the model showed that irrigation management (i.e., leaching fraction) is probably the most dominant factor in the development of salinity in the Wellton-Mohawk Irrigation District for the time period studied, 1968-1973.

Predicted salinization potentials were verified against measured salinities values taken from a salinity traverse performed in November of 1973. Verification results indicated a reasonably high agreement between predicted categories of soil salinization potential and potentials derived from measured field salinities. Approximately 86% of the salinization potential categories were correctly forecasted. A regression analysis of measured and predicted salinity values for the model produced a slope and y-intercept of 1.00 and -0.001, respectively, with a R^2 of 0.81.

L'EMPLOI D'UN SIG DANS LE REPÉRAGE DES ZONES OÙ IL Y A SALINISATION DU SOL DES TERRES AGRICOLES IRRIGUÉES

RÉSUMÉ

On présente des cartes qui délimitent les zones où il existe un potentiel faible, moyen ou élevé de salinisation du sol dans une région aride irriguée du district d'irrigation de Wellton-Mohawk, près de Yuma, en Arizona. Les cartes de potentiel de salinisation sont le résultat de la connexion d'un SIG, l'ARC/INFO, à un modèle de régression linéaire multiple qui établit le lien entre, d'une part, la salinité du sol et, d'autre part, les facteurs édaphiques et la gestion de l'irrigation. Plus précisément, la salinité du sol au site étudié est liée de façon linéaire à trois variables de régression : la fraction de lessivage, la conductivité électrique de l'eau souterraine et la perméabilité du sol. Le modèle de régression linéaire "le mieux lissé" montrait que la salinité du sol variait en raison inverse de sa perméabilité (cm/h) et de la fraction de lessivage, et en raison directe de la conductivité électrique de l'eau souterraine (ds/m), avec des coefficients de régression de 18,03, -0,4 et 1,32, respectivement, et un facteur stochastique ou une erreur de 2,12. La comparaison des salinités du sol mesurées et des valeurs prévues révèle un niveau élevé de corrélation, avec une pente de 1,0, un point d'intersection avec l'axe des y de -0,001 et un r^2 de 0,81. Une analyse détaillée du modèle montre que la gestion de l'irrigation (reflétée par la fraction de lessivage) représente probablement le facteur dominant de l'apparition de la salinité dans le district d'irrigation de Wellton-Mohawk pendant la période d'étude, soit de 1968 à 1973.

1. INTRODUCTION

Salinity pollution is an age-old problem of irrigated agriculture which is believed to have contributed to the decline of ancient civilization in the Middle East and North Africa. At present, salt is crippling agriculture production not only in North Africa and the Middle East, but also in North America, South America, Australia and Asia (Raloff, 1984). Though determining the exact acreage of salt-affected soils is difficult, the estimates are alarming. Today, salinity seriously affects productivity on an estimated 20 million hectares (50 million acres) of the world's irrigated land (Kovda, 1983). In the United States, nearly a fourth of all irrigated land is estimated to be suffering from salt-caused yield reduction (Arar, 1971). Though less menacing a pollutant than heavy metals or toxic organic compounds, salinity constitutes the most serious problem to water quality in many arid river basins (El-Ashry, 1985). However, because of the dynamic nature of soil salinity and the spatially-variable nature of soils, the true extent of salinity's affect on agricultural land is really not known. A means of predicting potential areas of development of soil salinity across the landscape is an essential tool in the assessment and management of soil salinity.

The principle constituents of the dissolved solids that constitute salinity in soil are the chlorides, sulfates and bicarbonates of calcium, magnesium, sodium and potassium. Salt accumulates in the soil profile primarily as a result of the processes of evaporation and transpiration. Salt, of course, does not evaporate nor is it taken up by plants; it stays in solution in the soil, thus increasing in concentration and posing a threat to plant productivity. At very high concentrations, certain salts precipitate out of solution.

In arid climates, the development of soil salinity on irrigated lands can be conceptually related to several general factors: irrigation water quality, physical edaphology, groundwater characteristics and irrigation management. The evapotranspiration process results in the concentration of salt within the root zone. These salts are present in the irrigation water. All things being equal, irrigation water of poor quality (i.e., high salt concentration) results in higher soil salinity profiles. Edaphic factors such as soil permeability are potentially influential in the development of salinity in soil due to the retarding effect upon water flow. A shallow water table and high salinity groundwater are also likely to be influential in the development of soil salinity as a result of the increased potential for upward

movement of salts (Ayers and Wescot, 1976; Shih, 1983). Irrigation management practices determine the extent of leaching of salts from the soil profile. Repeated application of irrigation water to land results in the accumulation of salts in the upper layers of soil. To maintain agricultural productivity, these salts must be leached out of the crop root zone. The fraction of irrigation water, in excess of a crop's need, that is applied to a field and percolates below the root zone is called the "leaching fraction". Leaching fraction is a common means by which irrigation management is measured and can be determined from the amount of irrigation water applied and the consumptive water use by a crop.

Salinity within irrigated soils clearly limits productivity in vast areas of the U.S.A. and other parts of the world. In spite of the fact that salinity buildup on irrigated lands is responsible for the declining resource base for agriculture, this country does not know the extent to which our soils are salinized, the degree to which productivity is being reduced by salinity, the increasing or decreasing trend in soil salinity development, and the location of contributory sources of salt loading to the groundwater. Suitable soil salinity inventories do not exist, nor do practical techniques to monitor salinity or to assess the impacts of changes in management upon soil salinity and salt loading.

Recent work at the U.S. Salinity Laboratory has shown that it is possible to determine the extent and degree of salinity development over an irrigated landscaped by coupling a knowledge of existing soil salinization factors (soil permeability, leaching fraction, depth to the groundwater and groundwater quality) with an automated geographic information system (Corwin et al, 1988; Corwin and Rhoades, 1988; Corwin et al, 1989). This paper presents an overview of the methodology developed in this work which results in the production of soil salinization potential maps for irrigated, agricultural land.

2. PROCEDURE

In essence, there were two procedural phases to the development of soil salinization potential maps: the organization and compilation of the data bases (Phase I), and the development and iteration of the salinization potential models (Phase II).

Phase I involved the development of a computerized data base of geocoded soil salinity data for a study area. The selected study site was an area of approximately 170 square miles of the Wellton-Mohawk Irrigation District located near Yuma, Arizona, in the southwestern United States (see Figure 1). The spatial data base consisted of soil type with its associated soil permeability, depth to the groundwater and groundwater quality contour data, and leaching fraction data aggregated to Public Survey quarter section units. Though pertinent to the development of soil salinity, irrigation water quality was ignored because it was assumed to be of uniform quality for the entire study area. This assumption was most likely valid because the source of the irrigation water was the same for all irrigated fields and the quality of the water was not temporally variable. Spatial data for the four salinization factors were compiled for the time period 1968-1973, a period in which no unusual perturbations (e.g., flooding) in the dynamics of the salinity development process for the study area had occurred.

Phase II involved the formulation and testing of the salinization model followed by the iteration of the model to the geocoded databank to produce a final map. In order to formulate and validate the salinization model, a salinity traverse data set of 66 sample sites (see Figure 1 for the sample site locations) collected by the University of Arizona in 1973 was used as the ground-truth measure of soil salinity for the top 61 cm (24 inches) of soil. The data set of 66 observations was randomly split into two data sets: an estimation data set of 29 observations and a validation data set of 37 observations. Each salinization factor was weighted according to its significance in the overall salinization process. The weighted significance ascribed to each factor was determined using standard statistical methods (i.e., multiple linear regression) which correlate the geocoded variables to the ground-truth measurements of salinity. In other words, regressor coefficients of the salinization potential model were derived by using multiple linear regression to fit the four salinization parameters to the ground-truth soil profile salinity measurements (meq/l) of the estimation data set. To determine which of the four regressor variables were significant, a variable selection procedure was used which would provide a large coefficient of determination (R^2), a small estimation of error variance (s^2) and a model which is parsimonious. After testing the model with the verification data set, an automated geographic information system, ARC/INFO, was used to display the map units. Applying the salinization potential model to the four salinization factor data bases,

the automated geographic information system computed map units which were subsequently assigned to one of three salinity categories as defined in the U.S. Salinity Laboratory's Handbook 60 (1954): low, medium and high, corresponding to salt concentrations of less than 7.5 meq/l, between 7.5-16.9 meq/l and greater than 16.9 meq/l, respectively. The maps were thereby a spatial expression of the salinity model.

3. RESULTS

Initial field studies using a Threshold Model approach concluded that the interactions between the four salinization factors were too complex to be related to soil salinity development by simply overlaying threshold levels of each salinization factor (Corwin and Rhoades, 1988). Rather, a means of weighting the significance of the individual factors to the overall salinization process was necessary. Subsequently, three multiple regression models were developed (Corwin et al, 1989). Each model differed in its functional form to reflect different interrelations between the salinization factors (e.g., upward movement and precipitation of salts on the surface, impeded downward movement of water with salt accumulation resulting form low permeability, and salt accumulation reflecting irrigation management efficiency).

Model 4 proved to be the best model both in its goodness-of-fit to the estimation of data set and in its ability to reliably predict the salinities of the validation data set. Model 4 consisted of three significant regressor variables: soil permeability (cm/hr), leaching fraction and groundwater electrical conductivity (dS/m). As shown below, the functional form of Model 4 indicated that the salinity (in meq/l) in the top 61 cm of the soil was inversely related to the soil permeability and the leaching fraction, and directly related to the electrical conductivity of the groundwater; and that the depth to the groundwater was an insignificant parameter:

$$\text{SALINITY (meq/l)} = 18.03 \times (1/\text{permeability}) - 0.40 \times (1/\text{leaching fraction}) + 1.32 \times (\text{groundwater electrical conductivity}) + 2.12$$

The R^2 and s^2 for this regression equation was a respectable 0.86 showing a fairly high degree of fit. The estimator of error variance,

s^2, was comparatively low, 2.59. Because the leaching fraction was not available for all quarter sections, a second regression equation for each model was also formulated. When leaching fraction data was not available then permeability and groundwater electrical conductivity were the significant regressor variables formulating Model 4:

$$\text{SALINITY (meq/l)} = 23.16 \times (1/\text{permeability}) + 0.84 \text{ (groundwater electrical conductivity)} + 1.26$$

The R^2 and s^2 for this regression equation were 0.60 and 10.64, respectively. The significant decrease in the R^2 and the increase in the s^2 when leaching fraction was removed as a regressor variable indicated that leaching fraction was particularly significant in Model 4.

The ability of Model 4 to correctly predict both the salinity category (low, medium and high) and to predict the actual measured soil salinity value was very good. Out of the 37 observations in the validation data set, Model 4 was able to predict 86% of the categories correctly. Even more impressive was the close prediction of actual measured salinity values in the validation data set. A linear regression of predicted salinity values from Model 4 and measured salinities resulted in a slope and y-intercept of 1.000 and -0.001, respectively, with an R^2 of 0.81. A plot of the residuals for Model 4 showed an ideal residual plot with a random pattern around zero and no detectable trend. This fact further established Model 4 as the most reliable model.

The map of salinization potentials generated from Model 4 (see Figure 2) indicated general trends in salinity which were known to exist for the study area over the time period of interest, 1968-1973. The southern half of the irrigation district is a mesa on which low salinity existed. Generally speaking, the northern half was predominantly moderate in salinity with pockets of low and high salinities.

4. CONCLUSIONS

There are several fundamental uses for regression models: prediction, variable screening, model speciation and parameter

estimation (Myers, 1986). A "good" model should be able to serve at least its intended purpose(s). So, even though a model may be the best predictive model, it may not necessarily be the best model for system explanation. For this study, not only was it desirable to predict salinity development potential from soil salinization factors, but it was also useful to obtain insight into the salinization process for the study site by using the model to explain or, more realistically, corroborate the expected interactions of the factors suspected of influencing the salinization of the root zone. The fact that Model 4 so closely fit the estimation data set and so reliably predicted the validation data set made it the most likely candidate for corroborating the interactions believed to cause salinization.

Model 4 indicated by the magnitude of its coefficients that electrical conductivity of the groundwater and soil permeability were the dominating soil salinization factors with leaching fraction having only subtle affects. In spite of this, Model 4 also showed that the greatest single increase in R^2 for a multivariant case occurred for the combination of leaching fraction and electrical conductivity of the graoundwater. This fact suggests that salinity development within the soil profile was more a consequence of the irrigation management with the groundwater electrical conductivity merely acting as a reflection of the leaching fraction and the electrical conductivity of the irrigation water. Several other facts point to irrigation management as the real predominant mechanism of salinity development in this particular study. First, the correlation matrix for Model 4 indicated a slight inverse correlation between groundwater electrical conductivity and leaching fraction; thus, indicating the possibility of a cause-and-effect relationship. Second, the total lack of significance of the depth to the groundwater to the development of salinity would remove the broad scale upward movement of salinity as a likely mechanism of salinization for this study area. Third, leaching fraction was moderately negatively correlated to soil salinity. Though the results are inconclusive, Model 4 points to irrigation management as the overall predominant mechanism for determining the development of salinity in the root zone for the study area and the time period of interest. Ostensibly, the high correlation of groundwater electrical conductivity to soil salinity development is actually a reflection of the irrigation efficiency and irrigation water salinity.

The ability to predict salinization potential from soil features and to spatially display them provides an invaluable tool for agricultural management purposes. It can serve as a means of locating salinity monitoring sites, to assist in formulating irrigation management practices or to select crops. Depending upon the level of significance of groundwater influences, the need for drainage systems can be assessed. Salinization potential maps can serve as a guide for determining reclamation needs or for deciding if cultivated lands should be brought into production or left untouched. Finally, an assessment of soil salinity can be made without labor-intensive field measurements of salinity by inventorying the extent of salt-affected soils as predicted from soil property relationships.

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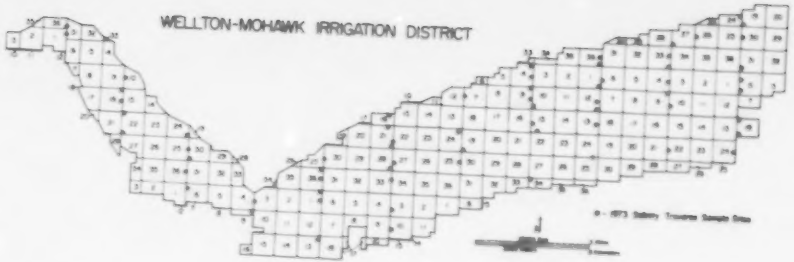

Figure 1. Wellton-Mohawk Irrigation District study area showing the section lines and the salinity traverse sample sites.

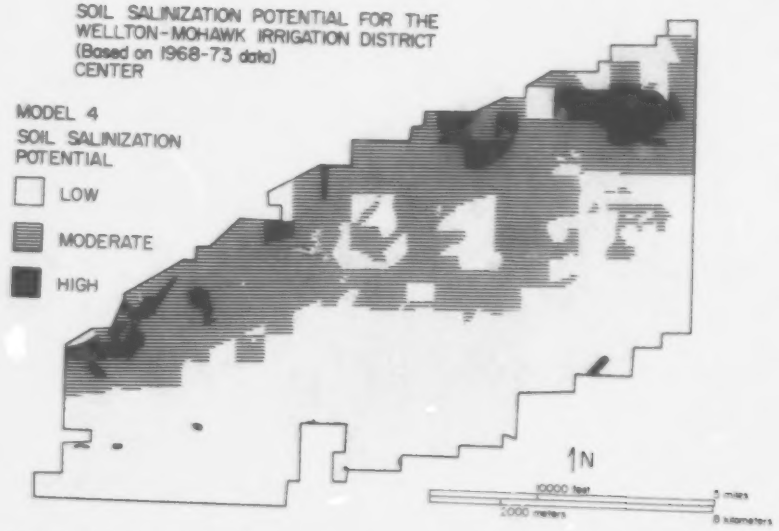

Figure 2. Soil salinization potential map generated from the "best fit" model (Model 4). Only the center section of the entire study area is shown for visual clarification of the graphic detail.

The Production of Topographic Maps Using A Totally Digital Cartographic Editing System

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Abstract

The Topographic Mapping Division (TMD) of Energy, Mines and Resources Canada (EMR), has recently acquired a new Cartographic Editing System (CES) to automate the production of the National Topographic Series (NTS) maps at the scales of 1:50 000 and 1:250 000 according to EMR's "Standards and Specifications for The Polychrome Map".

The cartographic process for the new system will be totally digital, from editing and text placement, to surface symbolization and reproduction. The new CES will not utilize any of the analogue methods traditionally performed.

The CES will receive "clean" vector data from various systems. Within the CES, this data will be processed where graphic editing, symbolization, text placement and map assembly will be performed. In the future, the CES will receive digital vector data from the National Topographic Data Base which will be the data base management and storage system for TMD map data.

The final plotting of the screen plate ready negatives will be performed by the Product Services Division (PSD) of EMR utilizing primarily the Scitex R280 or R300 plotting systems. The edited dataset will be sent to PSD using the "PostScript" vector formats or the Scitex "Handshake" raster format.

Through utilization of the new CES, TMD will be able to produce NTS maps more efficiently and economically as well as provide the user with a new product, the digital map.

LA PRODUCTION DE CARTES TOPOGRAPHIQUES AU MOYEN D'UN SYSTÈME D'ÉDITION CARTOGRAPHIQUE ENTIÈREMENT NUMÉRIQUE

RÉSUMÉ

La Division de la cartographie topographique (DCT) d'Énergie, Mines et Ressources Canada (EMR) a fait l'acquisition d'un nouveau système de rédaction cartographique permettant l'automatisation de la production des cartes de la série nationale de référence géographique aux échelles de 1/50 000 et 1/250 000 conformément aux normes et spécifications du ministère concernant les cartes polychromes.

Avec ce nouveau système, le processus de production des cartes (de la rédaction au positionnement des écritures et de la symbolisation des surfaces à la reproduction), sera entièrement numérisé. Il n'aura recours à aucune des méthodes manuelles classiques.

Le système recevra des données vectorielles "impartiales" provenant de divers systèmes. Il traitera ces données et procédera à la rédaction des éléments graphiques, à la symbolisation, au positionnement des écritures et à l'assemblage des cartes. Plus tard, le système recevra des données vectorielles numériques provenant de la Base nationale de données topographiques qui remplira le rôle de système de stockage et de gestion des données cartographiques de la DCT.

Le traçage final des négatifs prêts à photographier faits de données filtrées sera réalisé par la Division des produits et services d'EMR (DPS) au moyen, principalement, des systèmes de traçage Scitex R280 ou R300. Une fois édité, l'ensemble de données sera envoyé à la DPS sous formats vectoriels "Postscript" ou format de trame "Handshake" de Scitex.

Grâce à ce système numérique de rédaction cartographique, la DCT pourra produire les cartes du Système national de référence cartographique (SNRC) de façon plus économique et efficace, et pourra offrir à ses clients ce nouveau produit que sont les cartes numériques.

1.0 Introduction

The Topographic Mapping Division (TMD) of Energy, Mines and Resources Canada (EMR), has acquired a new Cartographic Editing System (CES) to automate the production of the National Topographic Series (NTS) maps at the scales of 1:50 000 and 1:250 000 according to EMR's "Standards and Specifications for The Polychrome Map".

The cartographic process for the new system will be totally digital, from editing and text placement, to surface symbolization and reproduction. This system will be replacing our current production system whose cartographic process is a combination of digital and analogue methods.

The purpose of this paper is to describe the procedure involved to acquire this system and the products that TMD wishes to produce with this system. This paper will also discuss the technology that this new system will employ and the reasons why TMD chose to utilize this technology.

2.0 Background

The Topographic Mapping Division currently uses a combination of digital and analogue techniques to produce it's 1: 50 000 National Topographic Series map sheets.

The digital portion of this process consists of an Intergraph system which was acquired over a period of five years from 1976 to 1981. This system consists of 3 workstations connected to a PDP 11/70 mini computer. Stereocompiled digital files are input into the system and then cartographically edited on the workstations. Some of the main cartographic editing activities performed on this system are:

- line symbolization.
- symbolization of bridges and rapids.
- displacement of buildings from roads.
- feature coding.
- deletion of non required features.
- digitization of cadastral limits.
- editing of congested areas.
- spacing of buildings.

Once editing is completed, these files are sent to the division's Plotting Section where the data sets are pre-processed and then plotted using two high precision Kongsberg flatbed plotters (one plotter uses pens and scribing tools to plot while the other uses a photohead, which flashes a light beam on film, to plot). Various reprographic materials produced by these plotters are:

- scribe of roads.
- scribe of screen band for cadastral boundaries.
- "flash" of cadastral boundaries and railway.
- "flash" on film positive of black features.
- "flash" on film of blue features.
- "flash" on film of contours.
- scribe of green key.
- scribe of intermittent blue key.
- scribe of marsh key.
- scribe of park key.

After plotting, these materials are manually prepared for printing. This tedious work involves scribe coat enhancement, peel coat creation, inspection, fix-ups, etc. It is also at this phase that toponymic and other text required for the map sheet are manually placed. Upon completion of the manual editing, all reprographic materials are quality controlled and re-edited if necessary. Upon final approval, these materials are sent to the Product Services Division (PSD) of EMR for plating and final printing.

3.0 Evaluation and Analysis

Since the acquisition of the current system, major technological advances have taken place which have revolutionalized the hardware and software used for digital cartographic editing. This new technology enables cartographic editing systems to process greater amounts of data at significantly faster rates and provides digital functionality which replaces the traditional analog techniques. Some of the major hardware and software developments now available for cartographic editing are:

- a workstation environment where each workstation functions with a dedicated CPU.
- WYSIWYG display. WYSIWYG (What You See Is What You Get) allows you to view on a colour screen exactly what you are going to print.

- colour raster plotters which are able to produce colour proof plots of the WYSIWYG image very quickly.
- high precision, large format raster plotters for the plotting of screen ready plate negatives.
- new interchage formats which allow the transmission of the WYSIWYG image to the plotting facility. The production of hardcopy reprographic materials are therefore not required.
- a full library of publishing quality text fonts.
- an application development platform for automating cartographic editing procedures.

Being aware of the hardware and software technology available today, the TMD perceived that the current CES was utilizing "old" technology which was both inefficient and costly. To verify this perception, the Division conducted an evaluation of the current system and a cost/benefit analysis.

The evaluation of the current system identified some of the following significant hardware and software limitations:

- hardware breakdowns due to age.
- many spare parts needed for repair are now hard to obtain due to age of the system.
- lack of a development platform for automating cartographic editing procedures.
- reliance on the time consuming process of producing, manually editing and maintaining hardcopy reprographic materials.

The purpose of the cost/benefit analysis was to analyse the throughput of the existing CES and its related costs and compare these with an estimate of the throughput and related costs of using a totally digital CES. The final recommendation of the cost/benefit analysis was that it would be much more cost effective to acquire and use a totally digital CES to produce EMR map products, than to continue using the existing CES.

In summary, the Evaluation and Cost/Benefit reports identified that the existing cartographic editing system has surpassed its expected life cycle, is slow, inefficient and costly. A system employing the latest technolgy could address the present system's limitations and produce maps more efficiently and economically.

4.0 TMD Requirements

Acting on the recommendation of the cost/benefit analysis, TMD conducted a market study to identify CES vendors and to obtain information about the digital technology available for cartographic editing systems. This information was used to better define the division's cartographic editng system requirements which would then be incorperated into a technical specification. This specification would be used for system acquisition. The following describes the technical specifications main acquisition requirements:

4.1 Data Input

The new TMD cartographic editing system must be able to receive "clean" vector data from various systems. "Clean" files basically mean that all polygons within the file must be closed and that the file should not contain any undershoots or overshoots. "Clean" files are needed to eliminate processing errors such as a colour bleeding from a polygon due to the polygon not being closed.

The new CES will initially receive stereocompiled data in either the ISIF or CCOGIF interchange formats. In the future, the CES will receive digital vector data from the National Topographic Data Base which will be the data base management and storage system for TMD map data.

4.2 Symbology

A cartographic editing system must have the capability of creating, displaying and placing symbology as defined by the EMR Polychrome Map Specifications. In order to do this, the system must be able to support point (ski, camping), line (hydro, railway) and area (marsh, flooded area) symbology that incorperates linear elements and polygon fills.

4.3 WYSIWYG (What You See Is What You Get)

A cartographic editing system should be able to display, at some stage, the WYSIWYG image of the completed digital map or a portion thereof. This image is required to allow for effective editing, map assembly and quality control by the operator. It is therefore essential that the WYSIWYG image as displayed on the screen is the same as the image plotted.

4.4 Publishing Quality Text Fonts

A cartographic editing system must be able to provide the capability of defining, displaying, placing and plotting all text fonts as required by the EMR Polychrome Map Specifications. These text fonts must be sufficiently defined so that they can be printed to publishing quality standards to maintain the clarity and quality of the map product. An optimal cartographic editing system should provide these fonts with the system so as to eliminate the very tedious task of having to create them.

4.5 Application Development

A cartographic editing system must provide the capability to develop applications to automate the procedures required to prepare the digital map. In order to do this, the application development language must be easy to learn and use, can be efficiently processed and must provide all the functionality and versatility required for automation. Production personnel have identified that the automation of cartographic editing procedures is the most important factor in making a cartographic editing system productive.

Since the development of applications are very long and tedious, an optimal cartographic editing system should provide sufficient functionality so as to minimize the amount of application development required.

4.6 Data Output

The cartographic editing system must be able to output the completed digital map to the high precision Scitex raster plotting systems located at PSD. These systems will be used to produce the screen plate ready negatives which are required for printing operations. This transfer process should be void of any manual intervention. The market study identified that most vendors provide this transfer process utilizing either the PostScript vector formats or the Scitex "Handshake" format.

The cartographic editing system must also be able to output the completed digital map to the Calcomp 54888 Colour Electrostatic Plotter, located at TMD, for the production of proof plots.

4.7 System Efficiency

The hardware platforms required for the cartographic editing system must enable the efficient processing of the large amount of data that makes up the NTS digital map. Critical to efficient hardware processing are the amount of dedicated main memory, the amount of dedicated storage memory and the processing speed. To achieve this high performance, TMD would like to acquire state-of-the-art workstation technology.

System efficiency is also dependant on the amount of software processes that are involved to produce the final product. In order to efficiently process large data sets, the number of software processes involved should be minimized.

Finally, system efficiency is also dependant upon the system and network configurations chosen.

4.8 Map Assembly

A cartographic editing system must provide the functionality to properly assemble a map to create the final NTS map product. Map assembly is primarily concerned with the ordered assembly of colours and features according to a priority that will ensure that the content, colour and clarity of features are preserved (i.e. preserve the colour and clarity of text when placed over a green area).

5.0 The Competative Bid

During the fall and winter of 1991, TMD utilized the competative bid process to select a vendor to supply the division with a new Cartographic Editing System. The technical specification was used as the basis for system acquisition. The evaluation of the bidder's proposals were based mainly on the following criteria:

- functional capabilities
- system performance (hardware, software, communication)
- price

The CARIS Cartographic Editing System produced by Universal Systems Limited (USL), Fredericton, New Brunswick, has been selected to supply TMD with a new Cartographic Editing System. This system was selected because USL's proposal best addressed the

selection criteria. Some of the components that will make up the cartographic editing system are:

- Sun SPARCSalton II workstations
  - UNIX operating system
  - 28.5 mips, 32 mbytes RAM memory, 848 mbytes disk memory
  - X Windows user interface
- SunServer 470
  - UNIX operating system
  - 22 mips, 64 mbytes RAM memory, 2.6 gbytes disk memory
- Hewlet Packard Laserjet III laser printer
- Sun 9 track ANSI magnetic tape drive
- Gentian digitizers
- 8 mm, 2.3 gbyte tape backup system

All hardware components will be networked to support the sharing of resources and data through the use of the TCP/IP communication and Network File System software.

6.0 Cartographic Editing System Products

Initially, the new CES will be used to produce EMR's traditional map products, the 1:50 000 and 1:250 000 NTS polychrome map sheets.

In the future, it is anticipated that the new CES will be able to provide the customer with an entirely digital NTS map complete with all symbology, text and colour. It is also anticipated that private industry will be using totally digital cartographic editing systems to produce NTS digital maps for EMR on a contract basis. To support this activity, TMD anticipates that it will be using the new CES as an inspection system for the production of NTS maps by contract.

7.0 Summary

The Topographic Mapping Division of Energy, Mines and Resources Canada, has acquired a new Cartographic Editing System to automate the production of the National Topographic Series maps at the scales of 1:50 000 and 1:250 000. This new system, whose process will be completely digital, will replace the existing cartographic editing system whose process is a combination of digital and analogue techniques.

The existing cartographic editing system was determined to be slow, inefficient and costly. This conclusion was reached because of the the system's reliance on "old" computer technology, analogue methods and labour intensive activities.

The new Cartographic Editing System was acquired to produce EMR's NTS map sheets in a more cost effective manner. This will be achieved by producing more maps per operator due to the elimination of labour intensive analogue techniques, the making use of much more efficient data processing units reflecting the latest technology, and by automating many of the cartographic procedures performed by the operators.

EVIDENTIAL REASONING FOR KNOWLEDGE INTEGRATION OF DISPARATE GEOGRAPHIC INFORMATION

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Abstract. The need to acquire and integrate knowledge from disparate data sources has exposed some weaknesses and limitations that exist between geographic information systems (GIS) and remote sensing image analysis systems (IAS). For example, classification and modelling procedures are often confounded by restrictions on data level, dimension and format, and cannot process uncertain information or data which violate important statistical assumptions. These difficulties of integrating disparate knowledge and the fact that most information exchange flows from the IAS to the GIS only has meant that the full potential of both systems has yet to be realised.

In this paper, a software system is presented for classification of multisource and multi-level data based on evidential reasoning. The system can analyse nominal (thematic) data from a GIS (e.g. soil maps, forest inventories) directly with original ratio level (non-thematic) data typically processed by an IAS (e.g. remotely sensed imagery, ancillary geomorphometric data). Evidence is gathered using a new frequency-based technique to compute support and uncertainty values for each input variable, from which event probabilities and class labels are determined by orthogonal summation. The capability of two-way information exchange between GIS and IAS is illustrated using an example of classifying permafrost in the Canadian sub-Arctic based on multi-source nominal and ratio level data.

RAISONNEMENT PAR MISE EN ÉVIDENCE POUR L'INTÉGRATION DE CONNAISSANCES D'INFORMATION GÉOGRAPHIQUE DISPARATE

Résumé: Le besoin d'acquérir et d'intégrer des connaissances provenant de sources de données disparates a exposé certaines faiblesses et limitations qui existent entre les systèmes d'information géographique (SIG) et les systèmes d'analyse d'images (SAI) de télédétection. Par exemple, les méthodes de classification et de modélisation sont souvent limitées par des restrictions sur le niveau, la dimension et le format des données. Ces méthodes ne peuvent donc pas traitées des informations incertaines ou des données qui violent d'importants postulats statistiques. Ces difficultés d'intégration de connaissances disparates et le fait que la plupart des flux d'échanges d'information vont du SAI vers le SIG, veut tout simplement dire que le plein potentiel des deux systèmes reste à venir.

Dans cet article, un logiciel pour la classification de données de sources et de couches multiples est présenté. Ce logiciel est basé sur le concept du raisonnement par évidence. Le système peut analyser des données nominales (thématiques) d'un SIG (e.g. cartes pédologiques, inventaires forestiers) directement avec des données de niveau de rapport (non thématiques), typiquement traitées avec un SAI (e.g. imagerie satellitaire, données géomorphométriques auxiliares). L'évidence est recueillie en utilisant une nouvelle technique basée sur la distribution des fréquences. Cette dernière permet de calculer des valeurs de support et d'incertitude pour chaque variable d'entrée, par laquelle les probabilités d'évènements et les catégories des classes sont déterminées par sommation orthogonale. La capacité d'échange d'information dans les deux directions, entre le SIG et SAI, est illustré en utilisant un exemple de la classification du pergélisol d'une région subarctique Canadienne. Cet exemple est basé sur l'utilisation de données nominales de sources multiples et de niveau de rapport.

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1.0 INTRODUCTION

An integrated system approach has been identified to address, among other issues, the urgency to study, monitor, and understand complex environmental problems such as global climate change, desertification, ozone depletion, and acid rain and pollution induced forest decline (NASA, 1988). Central to this theme is the need to analyse *multisource data* which contain a number of measures from different information sources for a given location (e.g. data from digitised maps, scanners, airborne and satellite imagery). Depending on the type of information involved and the processing required, these data are often analysed using geographic information systems (GIS) or image analysis systems (IAS). However, unrestricted data integration and analysis has been delayed as a result of different formats used in the original specifications of GIS and IAS (e.g. vector, raster, respectively), and by the proliferation of non-standard data formats unique to commercial software vendors. This has caused substantial effort to achieve data transfer between systems by specialised reformatting software and/or mathematical transformation, with particular emphasis on transporting IAS products to a GIS for overlay analysis, display and map production.

Recently, attention has shifted to developing integrated data formats with more advanced data structures and analytical techniques to produce combined systems which offer both GIS and IAS functions. Although issues of incompatible data formats have, in most instances, been resolved, many of the theoretical problems and methodological inconsistencies surrounding conventional approaches to multisource data processing remain. For example, classification and modelling techniques usually resident in IAS and GIS, respectively, are often confounded by restrictions on data type (e.g. qualitative, quantitative, directional), data level (or scale of measurement, e.g. nominal, ordinal, interval, ratio), dimensionality (number of variables), statistical assumptions (e.g. conforming to prescribed frequency distributions), as well as being unable to handle uncertainty in data. Some or all of these issues are often pertinent to multisource data sets, particularly when advanced procedures must be applied to a greater number of disparate data sources to analyse complex phenomena.

This paper deals with some of the problems inherent to the integrated classification of GIS and IAS data. For example, statistical classifiers such as maximum likelihood decision rules are inadequate since they can only process a limited number of variables, each of which must: (i) be normally distributed; (ii) adhere to variance thresholds; (iii) be ratio level data; and, (iv) have no associated uncertainty. The latter three restrictions also apply to linear discriminant analysis classification procedures commonly found in statistical software packages. In terms of GIS data, any restriction on the scale of measurement associated with input variables will usually be

problematic since GIS typically possess a variety of data levels, with nominal level thematic information associated with vectors or polygons particularly common.

To address this need, a new software classification system based on evidential reasoning is presented. At the core of this method is the Dempster-Shafer approach to integrating information (Dempster 1967; Shafer 1976) for determining event probabilities and class labels. The power of this approach lies in its ability to handle numerous variables at any data level without the restrictions of an underlying statistical model, and to incorporate measures of uncertainty into the analysis. An example using simulated GIS data together with remote sensing imagery from an IAS to classify permafrost active layer depth in the southwest Yukon is used to illustrate the advantages of the evidential reasoning classifier in overcoming significant technical and methodological limitations which made possible the application of a mixed, multisource data set to a complex environmental problem.

2.0 EVIDENTIAL REASONING

The mathematical theory of evidence was first proposed by Glenn Shafer (1976) as an extension and refinement of Arthur Dempster's Rule of Combination (1967). The Dempster-Shafer approach provides a heuristic basis for combining evidence from diverse and multisource data sets (Dempster 1967; Shafer 1976; Goldberg *et. al.* 1985; Lee *et al.* 1987; Srinivasan and Richards 1990; Moon 1990; Wilkinson and Mégier 1990; Peddle 1991). First, a set of representative training data should be available from which evidence can be derived. In this research, an automatic, frequency-based approach to building a *knowledge look-up table* (KLUT) has been implemented, from which evidential interval values in the form of *support* and *plausibility* are derived. The KLUT consists of frequency histograms computed from the training data of each class for each source. Evidential support is computed for a given input value based on its frequency of occurrence in training data, while plausibility is calculated as the magnitude of evidence which fails to refute the proposition. For quantitative data (ie. at interval or ratio scales of measure), an optional moving bin can be placed over a histogram to extend training data knowledge over the dynamic range of the data source and reduce any bias associated with individual frequency counts. This approach permits evidence to be gathered consistently and objectively from multisource data of varying type, format, and scale of measurement (e.g. nominal level GIS data, ratio level remote sensing imagery). The magnitude of uncertainty associated with a given source is computed as the residual evidence not ascribed to a particular class (after Garvey *et. al.* 1981). The set of supports and plausibilities for each class, and the uncertainty value together constitute the mass function for the source under consideration.

Once a unit mass function has been computed for each source of a multisource data vector, the next step is to combine the evidence into one mass function from which a decision rule can be applied to assign a class label. The aggregation of source specific bodies of evidence into one resultant mass function is achieved using Dempster's Orthogonal Rule of Combination (Dempster 1967). The final step in determining a class label is the application of a decision rule to the total body of mass for a data vector. In this research, the decision rule is based on the maximum total of support and plausibility.

These ideas have been implemented in the **MERCURY⊕** (**M**ultisource **E**vidential **R**easoning **C**lassification of KL**U**T probabilities b**y** orthogonal summation{⊕}) software package (Peddle, 1991) which is written efficiently in the C programming language and runs as a suite of modules under the VAX/VMS and MS-DOS operating systems. The package can process vector data stored in an attribute-table together with raster (image) data, and is not restricted by the number or type of variables for use as evidence (eg. soil maps, hierarchical forest inventories, directional data, quantitative ratio level satellite imagery, nominal thematic data from an image classification or Geographic Information System). The software complements many existing GIS and image analysis tasks by adding the capability to handle non-ratio and mixed data sources with a superior method of determining class probability based on evidential reasoning.

3.0 MULTISOURCE CLASSIFICATION OF PERMAFROST ACTIVE LAYER DEPTH

The occurrence of permafrost (perennially frozen ground) is a complex environmental condition which is difficult to detect and monitor throughout large areas due to its dynamic sub-surface and temporal nature. The remote detection and monitoring of changes in the distribution of Arctic permafrost has been identified as an important scientific process of interest at the local, regional and global scale (Royal Society of Canada, 1989; JPL, 1989). Changes in permafrost distribution are of interest for several reasons. A decrease in permafrost area will likely result in an increased thickness of the active layer (ground overlaying permafrost which undergoes seasonal freezing and thawing). This could produce an increased danger of structural building failure and road collapse problems. Melting permafrost can also induce ground failures and slope instability that can cause mass wasting debris flows and land slides. The Arctic is also one of the most sensitive areas on Earth to global climate change (LeDrew, 1986; Luckman, 1989). Assuming a positive relationship between ground temperature and air temperature, then changes detected in permafrost distribution could be used as an environmental surrogate for input to a climate change model.

3.1 Study Area and Data Collection

The study area encompasses 100 km^2 of scenic and rugged mountainous terrain centered at 61°13' N latitude and 137°34' W longitude in the Ruby Range, southwest Yukon Territory, Canada, and lies within the Aishihik Lake region that has been designated an Environmentally Significant Area (ESA). The study area ranges in elevation from 813 m to 1755 m a.s.l., and is characterised by strong altitudinal trends of vegetation from organic terrain and white spruce forest in river valleys and lowland areas to mixed woodland and deciduous cover, above which alpine shrub and exposed bedrock occur on upland slopes and mountain summits.

A relevant climatic record for this study site exists from data collected from 1944 to 1966 at an abandoned airfield north of Aishihik Lake. This subarctic alpine area has a continental, semi-arid climate with mean daily temperatures of -24.3°C (January) and +12.1°C (July) and recorded extremes of -56.7°C and +30.6°C, with a mean annual precipitation of 248.3 mm attributed mostly to summer rainfall. The region lies well within the zone of discontinuous permafrost, and has a mean annual ground temperature of -2.1°C (recorded at 6.1 m depth) and a mean annual air temperature of -4.1°C (Brown, 1969).

A cloud-free SPOT-1 multispectral linear array (MLA) high resolution visible (HRV) image was acquired 21 July 1990 with an off-nadir viewing angle of +5.96° (west), solar elevation 48.9°, and solar azimuth 171.1°. Since topography is a major factor which influences the distribution of permafrost, the integration of a digital elevation model (DEM) with spectral image data was essential for classifying permafrost in this complex and high relief environment. The DEM for this study was generated by Gestalt Photomapper II stereo-correlation of 1979 1:60 000 scale black and white aerial photographs. The permafrost "ground-truth" information necessary for classification training and accuracy assessment was obtained from direct soil probe determination of active layer depth in the field.

3.2 Experimental Design

Three of the factors known to control the distribution of permafrost were selected as input to evidential classifications of permafrost active layer depth. The variables surface landcover, equivalent latitude and terrain aspect were selected since together they should capture some of the important topographic and vegetation relationships that are often indicative of permafrost properties. These variables were used in an earlier successful classification of permafrost occurrence from field data and remotely sensed variables, and are described in more detail in Peddle and Franklin (1992). Each variable was obtained and classified separately using (i) independent field observation and measurement, and (ii) simulated GIS data and remotely sensed imagery. As shown in Table 1, each variable has a different data type; for this study, the nominal landcover and directional aspect variables are considered as simulated GIS data since they

possess the same properties as GIS data which are difficult or impossible to process using traditional classification techniques (e.g. maximum likelihood classification on an image analysis system).

The classification of field data is used to test the validity of these environmental variables by determining the extent to which they are related to permafrost distribution and active layer depth. If the field measures are found to be sufficient and valid (in this case, by obtaining reasonable classification accuracy), then it is logical to classify and test the same variables obtained remotely.

In this experiment, field data for 507 sites were compiled and analysed. Where permafrost was detected by soil probe, active layer depths of between 15 cm and 45 cm were common, with measured extremes of 5 cm and 87 cm. Based upon the depths recorded, three active layer depth classes were determined at 25 cm intervals, with a fourth class for absence of permafrost (Table 2).

3.3 Ground Data Classification

At each site, the dominant landcover was observed and placed in one of nine classes. Precise field measures of slope and aspect were obtained by compass, and used with the study site's latitude read from a 1:50 000 scale topographic map to calculate equivalent latitude. Table 3 shows the full contingency table of active layer depth classification based on landcover, aspect, and equivalent latitude observed and measured in the field. Classification accuracies are expressed using the kappa co-efficient and in terms of the percent agreement with soil probe ground truth data. The overall classification accuracy was 82.8% (K=0.77) at 163 test sites. Discounting the permafrost absence class, which had the lowest individual class accuracy (78%, K=0.70), the three active layer depth classes had an average classification accuracy of 85%. The highest individual class accuracy of 91% (K=0.88) was obtained for the shallow depth class (< 25 cm), with class accuracies decreasing with depth. It is apparent that the environmental variables measured in the field were better suited for separating near-surface active layer depths. This may be explained by the surficial nature of the variables classified; a higher permafrost table (shallow active layer depth) may have a stronger relationship with variations in surface cover and topography.

3.4 Integrated Digital Image Classification

The remotely sensed and simulated GIS data were assembled as follows. Aspect and slope were computed from the DEM using GEDEMON software (Peddle and Franklin, 1990) and used with latitude from the topographic map to compute equivalent latitude. The landcover labels were obtained from evidential classification of the SPOT MLA image, MLA texture, and

geomorphometry computed from the DEM. The landcover classification accuracy of 91% (K=0.90) using the MERCURY⊕ software was the highest classification accuracy obtained after extensive comparison with maximum likelihood classifications and linear discriminant analyses applied to a variety of input combinations.

An overall active layer depth classification accuracy of 79% (K=0.72) was obtained using the simulated GIS and remotely sensed variables (Table 4). This is a significant result when the complexity and data sources involved are considered and was only 4% lower than that obtained from ground data. This confirms the utility of the environmental variables selected, and suggests that their remote estimation can be considered consistent with ground data and appropriate for determining active layer depth.

4.0 CONCLUSIONS

- The ability to process disparate data from GIS and IAS together represents a more powerful approach necessary to address more complex environmental problems.

- The theory of evidence, and in particular the orthogonal sum rule, provides an established and mathematically sound framework for flexible and unrestricted classification of multisource and disparate data, which otherwise are difficult or impossible to classify due to technical differences and methodological limitations that exist between GIS and IAS data and procedures.

- Evidential classification of three active layer depth classes from remote sensing data and simulated GIS variables had an accuracy of 79% compared to soil probe field determination of frozen ground, and showed good correspondence with results obtained through the classification of field data. The ability of the MERCURY⊕ evidential reasoning software to process these multisource data formulations was critical to the success of the permafrost active layer depth experiments. The results from this research indicate a distinct possibility for the detection and monitoring of regional permafrost using multisource digital data alone.

- The MERCURY⊕ evidential reasoning software developed in this research is independent of either a GIS or an IAS framework, and could easily be used with both systems, or with either system alone. It represents one approach towards achieving greater flexibility in image classification and general data analysis by the reduction of methodological limitations and through increased functionality in system integration.

5.0 ACKNOWLEDGMENTS

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Variable	Data Type	Field Data Source	Image Data Source
Landcover	Nominal	Observation	Landcover Classification (SPOT MLA image, DEM)
Aspect	Directional	Compass	DEM
Equivalent Latitude	Ratio	Compass, Topographic map	DEM, Topographic Map

Table 1: Field and image data used in separate evidential classifications of active layer depth.

Class	Active Layer Depth
1	< 25 cm
2	25 - 50 cm
2	> 50 cm
4	No Permafrost

Table 2: Active layer depth classes for the Aishihik Lake study area.

Classified Label -->	0	1	2	3	4	Total	%	K
Class 1:		31	1		2	34	91.18	0.88307
Class 2:		2	39	5	1	47	82.98	0.76879
Class 3:			3	26	3	32	81.25	0.76123
Class 4:		7		4	39	50	78.00	0.69610
Total:	0	40	43	35	45	163	**82.82**	**0.7697**

Table 3: Accuracy of evidential classification of active layer depth from field data.

Classified Label -->	0	1	2	3	4	Total	%	K
Class 1:		27	4	3		34	79.41	0.73366
Class 2:			38	7	2	47	80.85	0.72858
Class 3:			4	27	1	32	84.38	0.79625
Class 4:		10	2	1	37	50	74.00	0.65545
Total:	0	37	48	38	40	163	**79.14**	**0.72065**

Table 4: Accuracy of evidential classification of active layer depth from simulated GIS data and digital remote sensing imagery.

GIS: An Executive Decision Perspective

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Many experts have identified Geographic Information Systems (GIS) as one of the most strategic technologies available to the operation and management of organizations and agencies of the 1990's. GIS is one of those seductive technologies that has so many obvious applications for a diversity of organizations and agencies. In an environment where geographic location is a critical element in performing service missions, GIS provides many opportunities for significantly better service at lower cost.

Whether the technology is being applied to utility engineering, city planning, land zoning, bus routing or any number of geo-related applications, the notion of integrating decision and support information with geographic position (absolute location and relative location) is extremely powerful. This presentation approaches this technology in its fundamental form - a cost/benefit decision. It is an attempt to give some insight into critical elements of the technology, and relate them back to the decision making challenges.

SIG : Un outil pour la prise de décision

RÉSUMÉ

Pour de nombreux experts, les systèmes d'information géographique (SIG) constituent l'une des technologies disponibles les plus adéquates pour l'exploitation et la gestion des organismes des années 90. Le SIG est une technologie séductrice qui comporte une myriade d'applications évidentes, pour divers organismes. Dans un milieu où l'emplacement géographique est un élément critique des missions de service, le SIG fournit de nombreuses occasions d'offrir un service meilleur à coût moindre.

Que cette technologie soit appliquée aux services publics, à la planification urbaine, au zonage, à la détermination des circuits d'autobus ou à diverses applications à référence géographique, l'idée d'intégrer "décision" et "information" d'une part, avec "position géographique" d'autre part (emplacement absolu et emplacement relatif), est extrêmement intéressante. La présentation traite de cette technologie dans sa forme fondamentale, c'est-à-dire une décision coût-avantage. L'on tente d'éclairer certains éléments critiques de cette technologie et d'établir des liens avec les défis que constituent les décisions à prendre.

The Next Wave of GIS: The All-Relational Solution

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The Next Wave incorporates new choices and directions in major areas of GIS including software modularity, relational database management architecture, location transparency, and application development.

Commercial RDBMS vendors such as Oracle spend more on R&D each year than the entire GIS industry spends. The All-relational GIS offers full access to each RDBMS vendor's capabilities-providing tangible benefits. GIS will leverage of technologies like enterprise data access, security access control and tracking, rollback and recovery technologies, data archiving and retrieval, audit trail management and database administration.

This presentation will describe how all-relational GIS will increase flexibility and integrity of GIS.

L'avenir des SIG : une solution entièrement relationnelle

RÉSUMÉ

La prochaine vague apporte de nouveaux choix et de nouvelles orientations dans les principaux domaines des SIG, y compris la modularité des logiciels, l'architecture de la gestion des bases de données relationnelles, l'accès transparent aux endroits et la mise au point des applications.

Les fournisseurs de systèmes de gestion de base de données relationnelles (SGBDR) comme Oracle investissent plus chaque année en R-D que n'en dépense toute l'industrie des SIG. Le SIG entièrement relationnel permet un accès complet à chacune des capacités des fournisseurs de SGBDR, ce qui procure des avantages tangibles. Le SIG est le moteur des technologies comme l'accès aux données de l'entreprise, le contrôle et le suivi de l'accès, les technologies de reprise et de récupération, l'archivage et la recherche de données, la gestion de la vérification à rebours et l'administration des bases de données.

La présentation décrira comment le fait pour un SIG d'être complètement relationnel en accroît la flexibilité et l'intégrité.

Integration of GIS and Non GIS - The Corporate Approach

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The enterprise-wide approach to information systems effectively provides a solution for organizations who must meet ever increasing demands for improved services while trying to contain spending. Getting acomplete solution from a single vendor will not be effective enough to meed all your organizations information system needs. The ability to integrate component packages (including the ones you already use) into a full, end-to-end solution is vital for your organizations maximum effectiveness.

Leading organizations are no longer looking to implement GIS technology as separate, self-contained systems. Progressive organizations are already implemanting enterprise-wide solutions which are opening the path to incredible new applications that make users more productive and competive.

This presentation will focus on how GIS fits into the corporate information network, and the degrees to which system integration can be achieved successfully.

Intégration des SIG et des autres systèmes - L'approche globale

RÉSUMÉ

Les organismes qui doivent sans cesse améliorer leurs services, tout en tentant de restreindre les dépenses, peuvent adopter une approche généralisée à l'entreprise en ce qui touche aux systèmes d'information. Un fournisseur ne saura à lui seul répondre à tous les besoins en système d'information de votre organisme. La capacité d'intégration des composantes de logiciels (y compris celles que vous utilisez déjà) en une solution entière et complète est vitale pour que votre organisme fonctionne avec un maximum d'efficacité.

Les organismes les plus novateurs dans ce domaine ne tentent plus d'appliquer les SIG comme si ceux-ci étaient des systèmes séparés et autonomes. Ces organismes ont déjà mis en application des solutions généralisées pour toute l'entreprise, qui ouvrent la voie à de nouvelles applications intéressantes et rendent les utilisateurs plus productifs et compétitifs.

La présentation sera axée sur la façon dont les SIG s'intègrent dans le réseau d'information de l'entreprise et la mesure dans laquelle on peut atteindre une telle intégration des systèmes.

Defining Target Groups for GIS Product Training

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Abstract

The greatest training challenge a GIS vendor must face today is to provide adequate training for every type of user. Typically, users vary immensely in GIS knowledge and understanding. In any new GIS installation, there are likely to be individuals who have little or no knowledge of computer technology. Others in the same organization may have extensive EDP (Electronic Data Processing) backgrounds, but no specific GIS knowledge.

- How can user training requirements be clearly identified?
- How can these requirements be satisfied through an effective corporate training program?
- How can users identify training programs that optimize their use of GIS?

This paper addresses these questions and suggests ways to define training requirements that meet user needs. Examples are drawn from different GIS target groups. Suggestions for defining course content are based on a sample training-needs matrix. A checklist is provided for evaluating GIS product training programs.

RÉSUMÉ

Le plus grand défi en matière de formation auquel doit faire face aujourd'hui un fournisseur de SIG est celui de fournir de la formation adéquate pour chaque type d'utilisateur. En général, les usagers ont des connaissances et une compréhension très variables des SIG. Peu importe où l'on installe un SIG, il y aura probablement des gens qui n'ont à peu près aucune connaissance des ordinateurs, alors que certains de leurs collègues connaissent à fond le traitement électronique de l'information, sans toutefois connaître précisément les SIG.

- Comment peut-on définir avec précision les exigences en matière de formation d'un utilisateur?
- Comment peut-on répondre à ces exigences au moyen d'un programme de formation efficace, à l'échelle de l'entreprise?
- Comment les usagers peuvent-ils déterminer les programmes de formation qui leur permettront d'optimiser leur utilisation du SIG?

Cet article traite de ces questions et suggère des façons de définir les exigences en matière de formation pour répondre aux besoins des utilisateurs. Des exemples sont donnés de divers groupes cibles. Un contenu de cours est suggéré, fondé sur un exemple de matrice "formation/besoin". Une liste repère est fournie pour évaluer les programmes de formation en matière de produits SIG.

What Training is Needed?

Every new user should ask this question when evaluating or implementing a GIS. As GIS continues to expand into new applications and industries, vendors must also address this question. Training needs cannot be defined by either the vendor or the user working in isolation; they must be defined through open communication and cooperation.

Collecting Evidence

How does the GIS vendor determine what training is needed? He has to collect evidence. This task, called Needs Analysis[1], is necessary before the program requirements can be written. The results may also be used as justification for initiating or delaying program development. Needs Analysis techniques are basically the same, whether you are evaluating GIS operations or any other technical task.

Kay Tytler Abella lists six critical questions that must be answered before beginning:[2]

1. Should a Needs Analysis be done?
2. What information do I need to design the program?
3. What are the best sources available for the information?
4. What is the best way to get the information needed from the sources?
5. How will I compile, analyze, or summarize the information?
6. How and to whom will I give the information?

I want to focus on how these questions relate specifically to GIS.

Should a Needs Analysis be done? Yes. Each GIS application is new to users at one point; therefore, a training program is always required. In any situation where there is a gap between present job performance and desired job performance, a Needs Analysis can be used to identify the best solution.

What information do I need to design the program? Identifying the information needed to create a new GIS training program requires the course developer to know who the users are, what they do in their job, the type of data they use, and how they will use the GIS. In short, course developers must know detailed information about the user profile, common procedures, typical data, and typical scenarios before effective program development can begin. The rapid growth of the GIS industry and continuing changes in GIS education strategies have turned users into "moving targets."

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[1]Needs Analysis methodology is well documented in the education field. Rather than attempt to give a thorough description of the process, this paper briefly describes some common techniques, focusing specifically on GIS issues.

[2]Kay T. Abella, Building Successful Training Programs, (Reading, Massachusetts, 1987), p. 4.

What are the best sources available for the information? There are several sources that can be used. These fall into five general categories;

1. Users, or potential users—can tell you what they need to do and provide user profiles. Job descriptions outline user tasks and can be used for curriculum development.
2. GIS developers, application specialists and support staff—will be able to identify product capabilities, production methods, and common user requirements.
3. User support records and course evaluations for existing training programs—indicate areas where training is needed or where course material can be improved.
4. Academic/research institutions—are in the process of setting up and refining GIS programs. Evaluating local programs, such as standard university curriculums, can provide information on other potential sources of GIS education.
5. GIS training programs from a variety of vendors—provide insight into other available training. However, these are often unreliable sources because standards and capabilities change so quickly in the GIS field. There is also no guarantee that all vendors will have invested the resources to complete a comprehensive Needs Analysis.

What is the best way to get the information needed from the sources? Question, evaluate, observe. Needs Analysis is best performed using a combination of methods. Personal interviews with users at all levels can be expensive, but may pass on valuable information that would otherwise be lost. Observation of users also gives insight into typical tasks and training requirements. Asking users what they need in the way of product training, especially after they have been working for a while, is an extremely productive exercise, whether the interviewee is a workstation operator, an application developer, or a GIS manager.

How will I compile, analyze, or summarize the information? There are several ways to compile or summarize the data that is retrieved through the Needs Analysis. Training-needs matrices can clarify a lot of information in a small amount of space.

The user-needs matrix in figure 1 was created from a questionnaire used to equate job titles with broad task categories. This type of survey is often the first step in developing a full course curriculum. Subsequent matrices can be developed through personal interviews using specific questions aimed at defining the contents of an individual training program.

How and to whom will I give the information? A report summarizing the findings of your research should be given to the sponsors of the training program. Because not all of the information will be training-related, other key people should have access to this information; for example, product designers, user support representatives, and documentation specialists. In this way, user needs are communicated throughout the vendor organization and can be addressed appropriately.

Once each of these questions has been answered and the Needs Analysis completed, the information must be compiled into a requirements document. This document is the foundation on which the training program rests. The final program design must address each of the requirements identified in the requirements document. Deviating from this document can compromise the validity of the training program, as can inadequate Needs Analysis. Any GIS vendor that bypasses or skimps on the Needs Analysis stage runs a high risk of developing material that is obsolete before the ink dries on the page.

How Many Courses?

Needs Analysis can go through several iterations, first to define general, and then more specific training needs for different levels of users. Three things are likely to surface during this process:

1 There are many different levels of users, from data entry clerk to GIS manager.

2 There are many significantly different GIS applications (see figure 2).

3 Different organizations use substantially different data.

This leads to the dilemma faced by many GIS vendors: Where do vendors draw the line between multi-purpose and specialized training programs? How this question is answered ultimately determines the value of the product training program.

Multi-purpose or Specialist Training?

There are many common applications that a comprehensive GIS product is capable of addressing (see figure 2). Each one of these applications can be approached differently, using significantly different data. If each major category in table 2 is subdivided into common applications, there are 25-40 significant GIS application uses. Imagine the training scenarios and data required to provide each subdivision with application-specific training!

Most GIS vendors address this problem by focusing more on the type of operation being performed, than the sample data. Once the trainee returns to the office, he is often put through further training (developed in-house and usually procedural in nature) to become a productive worker in the shortest possible time. As the GIS site matures, vendor training is frequently bypassed as a way of cutting costs. This is not an effective way to minimize costs, however. The price of vendor training is significantly lower than the cost of interrupting productive workers to provide in-house training and creating employees that have incomplete knowledge of the application being used.

The way to rectify this situation is to supply training programs that significantly reduce the in-house training necessary after the trainee completes GIS product training. The best user training is that which enables students to be productive immediately after training, and provides them with the tools to increase their job skills over time.

The two most important factors in achieving this optimal training are:

- Accurate user Needs Analysis
- Course development that addresses the needs of the user

The Best-Fit Solution: Custom Training

Courses are developed on multiple themes when the demand is great enough to support the necessary development. Ideally, product training programs use appropriate materials and data and have examples that are pertinent to the user situation. But every work situation is unique. How can vendors provide appropriate training for all users?

The first step is to identify subject areas that are common to the majority of users; for example, graphic editing for workstation operators or computer cartographers. Specialized subjects, such as coordinate editing or raster image editing can be offered individually as course modules. Users can choose from a set of optional modules that pertain directly to their training needs. This approach allows users more flexibility in their choice of course content, and at the same time ensures that vendors use standard, well-prepared materials.

The increased value of customized vendor training reduces the occurrence of in-house training development and therefore, reduce the on-going costs to users.

The Cost of Training

GIS vendors and users use different criteria to evaluate the success of GIS product training. There is, however, one goal that everyone shares: keeping costs to a minimum.

Cost-effective GIS training is the aim of both the GIS vendor and the GIS user. How well the vendor manages the training process helps determine the profit-margin for everyone involved. Realizing a financial return depends on two tasks: planning and vision. For the GIS vendor, this involves effective market studies, user-analyses, and on-going evaluation of existing course material. It is equally important, however, that the new GIS user understands the value of comprehensive training, and includes sufficient training in the implementation plan and annual schedules.

Too often, the cost of purchasing a Geographic Information System receives more attention than the cost of training because hardware and software costs are easy to calculate and extremely visible. When the total cost of a GIS implementation is considered however, staffing can cost twice as much as the hardware and software.[3] In light of this statistic, it is easy to see that GIS product training can be critical to the financial success of a GIS implementation.

How can training costs be minimized for the user? In order to answer this question, let's look at some typical user training goals (table 1).

Solutions to user and vendor goals may conflict; for example, the user's requirement for application-specific training, as opposed to the vendor's desire to create and maintain multi-purpose courses. By approaching curriculum design creatively, both goals can be met without incurring excessive costs.

Course developers must be (or have access to) visionaries, to build courses that look to the future. Course developers must maintain a link with GIS marketing strategies to keep in touch with future trends. At the same time, they must keep up with both training technology and GIS technology: research must be an on-going goal. As new training tools appear on the market, users will look for them in the training packages. These tools should enhance the quality of the training program, however, or else they become gimmicks that are expensive to maintain.

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[3] H.J. Dickinson, and H.W. Calkins, *The Economic Evaluation of Implementing a GIS*, (International Journal of Geographical Information Systems, Volume 2 Number 4, Oct. - Dec. 1988), pp. 307-327.

Training Tips

There are many factors that can influence the success of any training program. Careful attention to the training environment and timing can make an enormous difference to the quality and effectiveness of the training program. The following list summarizes key factors that will improve the quality of GIS product training and help GIS managers maximize training dollars.

- Ask your GIS vendor to suggest appropriate training programs. Respect course prerequisites.
- Spend the time necessary to match employees to appropriate training programs. Don't waste money training the wrong people.
- Where possible, tell employees about their new job responsibilities. The more informed a student is, the more he can focus on relevant subject material. The trainer will then be able to focus on specific job skills.
- Don't send employees for training unless they will use their new skills immediately. When there is a lengthy gap between training and working on a new system, the effectiveness of the training drops dramatically.
- Participate 100% in training. Don't allow yourself (or your staff) to be called away repeatedly during class to attend to other responsibilities.
- Let the training organization know what was right and wrong with its training program. Be specific. Your comments and suggestions are valuable and could improve the level of training for future employees.
- Ask for expanded training on specific tasks that you know will be critical for your site. GIS vendors should be able to accommodate special requests within reason. Make sure these requests are sent well in advance of the training course.

What to look for...

First-time GIS users are often naive about GIS product training. Users should take time to evaluate vendor training as part of the complete GIS package, before purchase—vender commitment to high-quality training is extremely valuable.

If, after evaluating the training program, you can answer "yes" to each of the questions in table 2, you should feel confident that the vendor training program is reliable and flexible enough to get you up and running quickly.

Conclusions

GIS product training is critical to the financial success of a GIS implementation. Careful Needs Analysis on the part of the vendor, and thoughtful planning and evaluation on the part of the user can help ensure this success. Cooperation and communication between the GIS vendor and user during the Needs Analysis phase is essential, and helps alleviate future training costs. Effective training programs improve operations and, therefore, represent a significant savings to the overall implementation.

The best way for the user to ensure that appropriate GIS product training is developed is to know what to ask for. This knowledge can be gained by evaluating existing training programs and taking the time to consider training as an important element in both the GIS selection process and the implementation period.

Because of the wide range of GIS applications, vendors are often "under the gun" to produce several courses using different themes. Planning and designing flexible training programs can resolve many conflicting vendor/user requirements. Many roadblocks to effective training can be eliminated through careful planning by both vendors and users, making sure that the training is given to the right people at the right time, in a good training environment. Training materials become more effective when course developers and users work together.

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Description	User Category						
Basic keyboard	/		X	/			X
Basic GIS concepts	X	X	/	/	X	X	X
Tabular data entry	X	X		X	X		X
Graphic data entry	X	X		X	X		X
Map display	X	X	X	X	X		X
Tabular report generation	X	/	X	/	X		/
Projection manipulation	X	/	X		X		/
Plotting	X	X	X	/	X		X
Data analysis	X	/	X		X		/
Data modelling	X	/	X		X		/
Application development	X	X			X		
Macro development	X	X	/		X		/
Programmatic interface		X					
X Prime responsibility / Secondary responsibility	Application Specialist	Application Developer	GIS Analyst	Data Entry Clerk	Database Administrator	GIS Manager	Cartographer/ Workstation Operator

Figure 1—Sample matrix matching job tasks and job titles

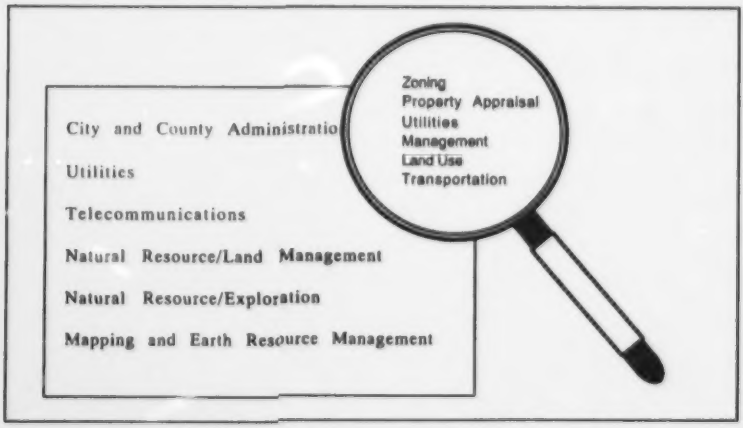

Figure 2—Different GIS Applications

GIS User Goals
Receive timely and effective training for all levels of users
Have access to custom training for specific needs
Receive training material that addresses the need for upgrade training following software revisions
Choose from a variety of available "off-the-shelf" courses
Grow and expand the use of the GIS over time
Work within budget constraints

Table 1—Training Goals

Question	✓
Have you seen outlines for each of the product training courses?	
Are the courses offered appropriate for your GIS application? Your vendor should be able to provide this information.	
Is the vendor willing to provide custom training if necessary?	
Do you have a choice of training location (vendor or user site)?	
Can you get training within a reasonable amount of time?	
Have you seen samples of training materials? Will they be useful for future reference and refresher training?	
Does on-line training data occupy a minimal amount of disk space? Do you have access to all the required equipment ?	
Are you looking at well designed exercises that will enable you to meet your production objectives? (Beware of re-hashed marketing material or user documentation.)	
Have you talked to other users about the product training program? Are they satisfied with the training they received?	
Does the vendor offer upgrade training? Will you be able to learn new functions with minimal effort?	

Table 2—Training Quality Checklist

Differential GPS: An Overview on the Use of Radio Beacons as a Means of Providing a Differential Service to Marine Users

Harvey Russel and Fred Forbes

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Non disponible au moment de l'impression

GIS Project Success: Applications for End-Users

David Vost, Manager
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In the coming years, geographic location will be an integral part of *every* information system. Geographic Information System (GIS) technology will be used as an operational tool throughout organizations. In this context, successful GIS projects will be those that provide access to the geographic data through easy-to-use applications tailored to the needs of the organizations end-users and customers. GIS implementation must take into consideration the requirements for building and maintaining end-user applications.

This presentation will look at GIS application development toolkits and their role in building end-user applications.

Succès des projets SIG : applications pour les utilisateurs finals

RÉSUMÉ

Au cours des prochaines années, les données sur l'emplacement géographique feront partie intégrante de *tout* système d'information. La technologie des systèmes d'information géographique (SIG) servira d'outil d'exploitation dans diverses applications et pour toute une gamme d'organismes. Dans ce contexte, un projet SIG fructueux sera celui qui donnera accès à des données géographiques au moyen d'applications faciles à utiliser, et conçu spécialement selon les besoins des clients et des utilisateurs finaux des organismes. La mise en oeuvre des SIG doit tenir compte des exigences d'élaboration et de maintien des applications pour les utilisateurs ultimes.

Les auteurs se pencheront sur les boîtes à outils pour la mise au point d'applications dans le domaine des SIG et sur le rôle de celles-ci dans l'élaboration des applications pour les utilisateurs finaux.

Building Spatial Databases From Dgital Maps

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Many users of spatial data have made major investments in digital mapping and CAD graphics over the last fifteen years. Most of these users are in the vanguard in implementing GIS technology but are faced with the significant data conversion problems in restructuring their digital maps for use in a spatial database. Many of the capabilities of a GIS can, in fact be successfullyexploited during the data conversion process to extract intelligence from digital graphics. Intelligent symbology, spatial searching techniques and automated data restructuring are examples of tools that can be used to derive intelligent spatial data from digital maps and CAD graphics.

This presentation discusses methods for optimizing data conversion procedures and maximizing the spatial information transfer from a digital mapping environment to a Geographic Information System.

Élaboration de bases de données spatiales à partir de cartes numériques

RÉSUMÉ

De nombreux utilisateurs de données spatiales ont réalisé des investissements majeurs dans le domaine de la cartographie numérique et de l'infographie au cours des quinze dernières années. La majorité de ces utilisateurs sont à la fine pointe dans le domaine des SIG, mais doivent faire face à des problèmes importants de conversion de données lors de la restructuration de leurs cartes numériques en base de données spatiales. Nombre des capacités d'un SIG peuvent en fait être utilisées avec succès au cours du processus de conversion des données en vue d'extraire des données significatives des infogrammes. Le report de symboles signifiants, les techniques de recherche spatiale et la restructuration automatisée des données sont des exemples d'outils qui peuvent servir à obtenir des données spatiales significatives des cartes numériques et des infogrammes.

Les auteurs discutent ici des méthodes d'optimisation des techniques de conversion des données et de maximisation du transfert d'information spatiale d'une carte numérique à un système d'information géographique.

An Integration of SCADA and GIS

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Abstract

Supervisory Control and Data Acquisition (SCADA) systems are used to control many types of plants, oil field and pipeline operations, telecommunications and utility networks, and many other industrial operations. These systems have evolved to utilize computer databases and multiplexed field devices between which data and control signals are passed in real-time. Most SCADA applications cover a significant geographical area in which man-made and natural geographic features can be relevant to normal operation and emergency response. Hence, a potential next step in the evolution of SCADA is integration with a geographic information system (GIS).

In prototyping the integration of existing SCADA and GIS packages at Hughes Aircraft of Canada Limited, we found that a host of issues needs to be addressed. One of the first decisions was to determine whether the real-time, fault-critical SCADA component or compute-intensive GIS component should have overall control. Daily operations and emergency response requirements should be used to consider which GIS analysis and data retrieval functions are useful and can reasonably be performed on-line. In support of these functions, the data must be split between the SCADA and GIS components and a parallelism developed between these two halves. Based on the functionality, data organization, and the limitations of the component packages, it was necessary to determine the means of data and command exchange between the two components. This paper documents the decisions we made and potential uses we found in the integration of existing SCADA and GIS packages.

1.0 Introduction

Supervisory Control and Data Acquisition (SCADA) technology is used to control many different industrial processes and systems ranging from telecommunications and distribution utilities to sewage treatment. Many current SCADA systems exchange data and control signals with multiplexed field devices in real-time and present the system status to human operators on graphics workstation screens in the form of schematics and simulated control panels. The ability for opera-

Intégration des SCADA et des SIG

RÉSUMÉ

Les systèmes SCADA (Supervisory Control and Data Acquisition) sont utilisés pour le contrôle de nombreux types d'usines, l'exploitation de pipelines et de champs pétroliers, les réseaux de services et de télécommunications et nombre d'autres activités industrielles. Ces systèmes ont évolué et utilisent maintenant des bases de données informatiques et des dispositifs multiplexés sur place entre lesquels passent, en temps réel, les données et les signaux de commande. La majorité des applications des SCADA couvrent une superficie importante dans laquelle les caractéristiques géographiques naturelles et anthropiques peuvent modifier les opérations normales et les réponses en cas d'urgence. Il semble donc approprié de penser à intégrer un SIG au SCADA.

Lorsque nous avons étudié le prototype d'intégration des progiciels SIG et SCADA existants chez Hughes Aircraft of Canada Limited, nous avons découvert une quantité de problèmes à résoudre. L'une des premières décisions à prendre était de déterminer à laquelle des composantes SCADA (sensibles aux déficiences, en temps réel) ou SIG (traitement numérique) on donnerait la régie. Les exigences pour l'exploitation quotidienne et en cas d'urgence devraient être utilisées pour déterminer quelles fonctions de recherche de données et d'analyses des SIG sont utiles et peuvent être effectuées en ligne de façon raisonnable. À l'appui de ces fonctions, il faut partager les données entre ces deux composantes (SCADA et SIG) et créer un parallèle entre ces deux moitiés. Il est nécessaire de déterminer les moyens d'échange de commandes et de données entre ces deux composantes selon la fonctionnalité, l'organisation des données et les limites des logiciels des composantes. Cet article traite des décisions prises et des utilisations potentielles de l'intégration des progiciels SIG et SCADA existants.

tors to access and analyze a geographically correct representation of the facilities they are managing is a strong justification for the integration of GIS and SCADA. We have begun to explore the potential of this union with the integration and testing of existing GIS and SCADA packages.

2.0 Real-time, Event Driven Response -- Who is in control?

SCADA systems are considered to be real-time computation and control systems even though their timeliness does not typically compare with, for instance, the targeting and control systems found in aircraft. Most often, a SCADA system operates with a cycle time on the order of 0.1 to 10 seconds. Within this time, it must:

- poll data (or service interrupts) from a diverse set of geographically separated end-devices,
- monitor data and control input from a human operator,
- perform computation with this data,
- update the operator's display,
- update an internal state database,
- send any required control signals and data to the end-devices.

Although certain self-responsive end-devices, such as circuit breakers, may have millisecond response times, this is without the intervention of "supervisory control". Instead, the fact that a self-responsive end-device has changed state would be transmitted to the SCADA system which then performs higher level math, logic, and data display operations pertaining to the system as a whole; why did the end-device changed states and what should be done about it? In contrast to fast acting end-devices, control actions requiring input from a human operator may take on the order of seconds or minutes depending on the operator's attentiveness and the criticality of the situation.

Regardless of the time scale of the events that occur within a SCADA system, the system is event driven. The significance of the events varies from minor fluctuations where automated control can keep the system in nominal functioning range to major faults requiring operator action. Thus when integrating SCADA and GIS, one of the first decisions is to determine whether the real-time, fault-critical SCADA component or compute-intensive GIS component should have overall control.

If the GIS component is not required to be active, for instance using the GIS to create pre-formatted graphics for later display by SCADA, then control can remain with the SCADA component. One of our requirements, however, was that the GIS be an active component so that at least some of the GIS functionality could support moment by moment system operation. To satisfy this requirement, we decided that the GIS component should act in support of the SCADA component, which retains overall control.

We had two reasons for this decision. First, a GIS is usually command driven, not event driven and the control logic in the SCADA component is considered to take priority. We might devise uses where the GIS can control SCADA. For instance, the GIS performs a network analysis of a gas processing/transmission system to determine a set of valves to close and then commands the SCADA to do so. Unfortunately, this approach has the potential danger of bypassing fail-safe SCADA control logic and proper event sequencing. It is possible to program safe-guards in SCADA against incorrect event generation from a GIS, however, the number of combinations of entities selected by the GIS in any given scenario makes exhaustive testing difficult. Alternately,

with SCADA in control, we can still have the GIS perform the same analysis operations and then display the results to the operator to aid in decision making. Also, having the GIS in control may conflict with existing industrial regulatory requirements.

Second, we wanted to provide GIS functions to SCADA users, not SCADA functions to existing GIS users. Keeping SCADA in control allows SCADA users to remain in a familiar environment. So, in our approach (Figure 1), SCADA transforms certain events such as operator or end-device input into GIS commands which cause GIS display updates, attribute reports, and analysis operations.

3.0 GIS Functionality

The GIS functionality we selected for inclusion in our prototype is by no means an exhaustive or optimal set. However, to reduce the problem scope to a manageable size, we imposed two constraints: that the GIS be used on-line and that the GIS skill required by the operator be minimized. The first stipulation puts aside some of the administrative, data management, and longer term applications which use GIS in an off-line manner. One of these applications, developed by Union Electric of St. Louis, Missouri [Proctor, 1991] is the use of their AM/FM database to update their SCADA system. The AM/FM graphics and attribute data, which describe their distribution facilities, are occasionally downloaded to the SCADA system in standard interchange format (SIF). The data transferred to the SCADA system are used as graphics interface screens and as part of the circuit model. This method of maintaining consistent and current data company wide is a great benefit for utility companies which have constantly changing systems.

By minimizing the GIS skill required by the operator, our intention was to make the GIS blend with the SCADA style of push button control with few superfluous or distracting features. To realize this requirement, we found it convenient to assign three categories of GIS functions:

- generic context insensitive
- generic context sensitive
- specific context sensitive

The *generic context insensitive* category includes functions which can be performed on the current GIS graphics display, without regard to the SCADA system. The functions we made available in this category are zooming, panning, labelling, distance measurement, and attribute reporting. Attribute reporting in this case means to select an entity on the GIS graphics screen with the cursor and receive a text report listing the entity's attributes and their values. These functions are always available to the operator and are initiated with the push of a graphics button. Other potentials for this category are functions to report map grid coordinates at the cursor location (especially relevant for companies having their own grid system) and to report the street address at the cursor location. Many more functions could be placed in this category, however we aimed to eliminate functions that would be used infrequently.

Functions in the *generic context sensitive* category are sensitive to the context of the SCADA system or user interface. Typically, a SCADA operator would traverse a hierarchy of graphical schematics and annunciation and control panels while checking statuses and initiating control actions. Functions in this category are performed on the last entity the operator has visited or accessed

through the SCADA interface. If we call this the *active entity*, then these functions are generic in the sense that they are applicable and essentially the same no matter that the active entity might be a valve, a fire detector, a circuit breaker, a pump, or a building at a plant site. The functions we made available, at all times, in this category are:

- *View Point* - update the GIS graphics display to contain the active entity and any other surrounding, related objects within a predefined set of extents. The active entity is labeled and may be plotted in a color signifying an alarm or other important state.
- *Highlight Point* - similar to View Point except that an attempt is made to plot the active entity in the current GIS view. If it is not within the current extents, the active entity would not be plotted.
- *Report on Point* - display an attribute text report for the active entity and present a list of specific, context sensitive functions from which the operator can pick. The actual contents of the text report and function list will vary for different active entities.

The attribute reports were found to be useful for providing information such as equipment make and model, names and phone numbers of emergency contacts, and other such parameters.

The *specific context sensitive* category is where access to some of the more powerful GIS functions can be found. These functions are context sensitive as described above, and they are also specific to the active entity and the active entity's state. When the *Report on Point* function is selected, it displays a list of specific functions whose contents depends on the active entity and its state. Because these functions are directly related to the SCADA application domain they are best illustrated by taking examples from our prototype.

The prototype consists of a simulated gas processing facility supplied by three natural gas wells through a pipeline. The facility separates water from the gas, compresses the gas for retransmission, and injects the water back into the wells. Within the wells and facility buildings are various valves, metering devices, ultra-violet fire detectors, H_2S gas detectors, and other devices which are all monitored and controlled by the SCADA system. Some of the specific GIS functions available for the fire detectors are:

- *Show Nearest Fire Extinguisher* - find and highlight, on the GIS graphics screen, the fire extinguisher nearest to the fire detector.
- *Show Detector Range* - plot a polygon showing the visual range of the ultra-violet eye of the fire detector. Since multiple detectors are usually set around the interior perimeter of a building or detection area, plotting the overlapped ranges of detectors in an alarm state can help pin-point the fire location or diagnose spurious detection.

One specific function we have for H_2S gas detectors is *Show Danger Radius* which plots buffer zones around H_2S gas detectors based on the H_2S concentration reported by the detector. Within these specific functions we find that basic GIS analysis functions are very useful to the SCADA operator simply because they have been tailored to specific physical entities in the SCADA environment.

These categories maintain a set of concise and often sophisticated functions available at the push of a button without requiring extensive GIS experience. They also require that the designers responsible for the GIS component prepare a well defined set of functional requirements in consul-

tation with the eventual system operators and plant designers. One cannot prepare a set of functions for the *specific context sensitive* category without knowledge of the system being controlled.

4.0 Data Organization

The next major challenge to integrating a SCADA system and a GIS is deciding what data should be stored in which component. Most GIS and SCADA systems have their own internal databases which are usually proprietary. In addition, most GIS's have links to external commercial off-the-shelf (COTS) databases such as Oracle, Ingres, Sybase, Informix and others. Thus some difficulties lie in the fact that a mechanism has to be designed to integrate the two dissimilar proprietary databases; allowing the two to share and retain information in the most optimized manner. We will discuss the specifics of data communication between the two systems in the next section. In this section we will concentrate on the design of the databases in light of storage economy and retrieval efficiency.

We mentioned in section two that a SCADA system is a real-time event driven system while a GIS is command driven. The first question to ask for the data organization design task is how to place the data so that the real-time aspect of the SCADA system would not be compromised by the slower response GIS system? The next question to ask is how can one tie together the two databases such that when a reference is made to an entity in the SCADA system, the same entity will be recognized in the GIS system or vice versa? Or in other words, is there any common scheme one can employ to tie both systems together?

To answer the first question, we investigated the nature and the architecture of both databases before deciding how the data are to be distributed. A typical SCADA application might manage hundreds of remote terminal units (RTUs), and each RTU might look after dozens of control signals for one or more end-devices. In addition, each control signal requires several fields of storage in the database. For example, in our gas plant simulation, the plant site has three main facilities: a separation facility, a compression facility and a water injection facility. Within the separation facility and for each incoming pipeline, there is an orifice meter and other transducers. Together these devices measure and transmit the following: flow rate, flow temperature, flow pressure, choke position, choke status, choke control, emergency shutdown valve (ESDV) status, and ESDV control. The data organization and storage requirements for each device can be depicted by the following format, shown for an orifice meter:

Attribute Name	Attribute Type	Data Type	Initial Value	Current Value
flow rate	SCALAR	double	[measured]	150.1
flow setpoint	SCALAR	double	100.0	120.3
ESDV status	SCALAR	boolean	OFF	OFF
.				
.				
.				
temperature	SCALAR	float	[measured]	87.
temp_last_3	VECTOR	float	60., 65., 78.,	65., 78., 87.

Thus a high-level conceptual view of the SCADA database can be drawn, using a tree hierarchy, as in Figure 2. However, the actual implementation of the database might be based on a hierarchical database format or a table-like relational database format.

In typical vector-based GIS software two types of data are stored in the database. The first type is called spatial data and the second type is called attribute data. Spatial data describe the location and shape of geographic features and their spatial relationships to other features. Attribute data are descriptive information about the geographic features. Together, they form the basic set of information that can be a source for deriving further information. For example, geographic features like gas well points, rivers, building layouts, site boundaries, and lake shorelines together with attribute data such as elevations and chemical content can yield more information by using the geographic analysis capability of the GIS.

There is no doubt that the spatial data is more efficiently stored in the GIS database than the SCADA database, but the attribute data could be stored in either or both of the SCADA and GIS databases. In our implementation, we have derived several categories that help us classify attribute data:

- Attribute data that require real-time retrieval or are used to derive real-time information - stored in the SCADA database
- Attribute data that describe control devices but do not require real-time retrieval - stored in the GIS database
- Attribute data that describe geographic features and require real-time retrieval - stored in the SCADA database
- Attribute data that describe geographic features but do not require real-time retrieval - stored in the GIS database

The issue of how to tie the two databases together was addressed by determining the degree of integration of the two systems. In our prototype, the SCADA system is the driving force and communication is mostly one way; meaning that the SCADA system controls the execution and information is likely to be passed from the SCADA component to the GIS component and not the other way round. The GIS performs on-line analysis and display mainly to assist the operator in making decisions but not to automatically cause any functions to execute in the SCADA component. To allow the GIS to do its analysis, certain device information and user-interface information has to be passed from the SCADA component to the GIS component. We have defined the following attributes to be added to the SCADA database for each entity to provide the common data structure for the communication:

- gis_tag - the tag used to identify the same entity in both databases
- gis_maps - a list of maps in which the tagged entity, related entities, and background graphics are found
- gis_extents - the distance indicating the size of the surrounding area to initially display for this tagged entity
- gis_color - the color in which to plot the entity
- gis_is_alarm - a flag indicating the alarm state of the entity

This list of attributes could be lengthened, but the main quality of these attributes is that they are

domain independent and can apply to any type of physical entity in the SCADA system. Every GIS command sent from the SCADA component will be sent with these attributes. GIS commands requiring more specific information can request that information from the SCADA system using the tag value to reference the appropriate entity.

5.0 Interface

5.1 SCADA-GIS Interface

Within our prototype, the GIS behaves much as it would if it were running stand-alone. The GIS continues to execute its native command set and display text and graphics results, but instead of being driven by user commands, the commands are provided by the SCADA component. In our UNIX based implementation, the GIS has been modified to accept text command input from an Internet socket instead of a user's terminal (mouse cursor input to the GIS graphics screen remains unchanged). Within UNIX and Internet, a socket is a communication protocol with associated data structures and function libraries which can be used to replace files and terminals as I/O devices. When operator input to the SCADA component requires GIS action, the SCADA component "pipes" a GIS text command script along with the attribute arguments listed in the previous section to the GIS through the Internet socket.

This method is simple but effective and has a number of advantages. Different GIS packages can be integrated by translating the GIS data to the proper format and by replacing the GIS text command scripts with commands appropriate to the chosen GIS. GIS functionality is modified and supplemented by changing the scripts. Finally, Internet sockets work across a network such that the GIS and SCADA components can run on separate hardware.

5.2 User-Interface

The user-interface is a very important part of the system. The control-room operator has to continually interact with the system and make decisions based on whatever knowledge can be extracted from the screen. The user-interface has to be designed such that it will reduce fatigue and at the same time optimize the efficiency of the operator. The two key issues we addressed when designing the user-interface are:

- Heterogeneous computing environment,
- Screen management.

It is often the case that the SCADA system and the GIS run on different computing platforms. The GIS is more flexible than the SCADA system in that many GIS vendors support a wider range of hardware platforms. In a heterogeneous computing environment, issues such as operating systems, communications protocols, graphics and windowing standards, have to be resolved before designing the user-interface.

In our implementation, both systems run on UNIX, and both support the X-Windows graphics and windowing protocol. The X protocol was originally developed by MIT and is intended to be a standard independent of hardware and operating systems. The use of a standard and widely accepted graphics and windowing protocol promotes software portability and also allows the creation of a homogeneous interface across a heterogeneous environment. This lets the control-room operator

work more comfortably with the integrated software. With a common protocol, there need only be one screen console to display both systems even if they do not run on the same hardware. X-Windows also has the advantage that COTS Graphical User Interface(GUI)-builders are available to create the interface, which can greatly reduce development time.

Whether custom code is written or a GUI-builder is used to create the user-interface, a decision needs to be made regarding how to make the most use of screen space on the console, what kind of information will pop-up at what time and how to use color. The idea is to manage the screen in an orderly way so that the operator would not be distracted by the vast amount of information (graphs, schematics, maps, text) that are to be shown. In our design of the user-interface, we conform to the following constraints for better screen management:

- The pop-up windows for the SCADA system are shown mainly on the left side of the screen, and the graphics and text windows of the GIS are shown on the right. Though the user can move the windows anywhere at will, the left-right split is the default. This way the operator can more easily recognize that information change has occurred in either the SCADA or GIS component according to which part of the screen has been updated.
- The transient control panels and menus for the SCADA functions and GIS functions pop-up around the middle of the screen. This minimizes the overlapping on the SCADA and GIS windows and promotes faster operator response. Static or "permanent" menus for SCADA functions are displayed in the form of a pull-down menu bar on the top of the screen. Those menus for the GIS functions are contained in a pop-up menu that is placed on left side of the screen so as not to cover the GIS windows and to minimally cover the SCADA windows.
- Since the SCADA side is responsible for most of the window traffic (displaying schematics and control dynamics at different levels of the device hierarchy), window sharing is sometimes used on the SCADA side. By window sharing, we mean that some screen images may replace other images in the same window instead of always creating new windows.
- A common style is used for both systems in windows and buttons design, as well as in window dialog sequence.
- A common coloring scheme is used for both systems. In our implementation, same color is used for a device in both the SCADA schematics and the device symbol in the GIS maps. Red is used for device alarm on both systems.

6.0 Conclusions

We found our approach to the integration of SCADA and GIS to be effective in the creation of our operational prototype. Many issues we did not address include: contention for the GIS should some functions take a long time to complete, and optimal GIS map design using cartographic techniques adapted to the different SCADA domains. Feedback from SCADA users and developers indicates that there are many possibilities for the integration of SCADA and GIS. Such integration will require effort from all the disciplines involved in a particular application whether it be telecommunications, electricity distribution, oil and gas, or any other.

Acknowledgement

We would like to acknowledge the contribution of Hewlett-Packard (Canada) Ltd. to this work.

Reference

Proctor, H.C. et al [1991] AM/FM/GIS and SCADA, Geo Info Systems, Aster Publishing, October 1991.

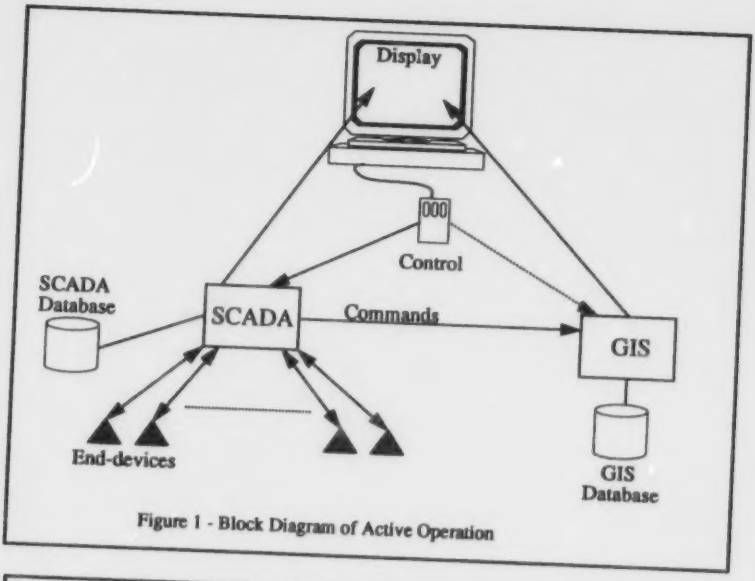

Figure 1 - Block Diagram of Active Operation

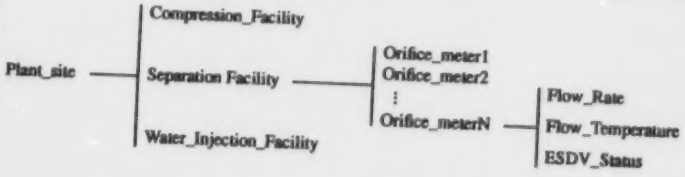

Figure 2 - Tree hierarchy for the SCADA database.

School Bus Routing using a GIS

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Abstract

The School Bus Routing Problem (SBRP) consists of finding a set of school bus routes to provide qualified students with transportation from their residences to and from their school subject to limits on a grade specific maximum distance that each student can walk from home to school.

This application involves the manipulation of a large amount of geographically referenced data such as the street network and the student information. TransCAD, a microcomputer-based GIS designed for transportation applications, was used as a data management platform for the implementation of a system for the Urban SBRP.

The routing system was implemented as a set of four inter-related modules for data maintenance and route generation and integrated into the TransCAD meaning system. The information storage was organised into four database layers. The system was empirically tested in the City of Guelph with data obtained from the Wellington County Board of Education.

ÉTABLISSEMENT DES ITINÉRAIRES D'AUTOBUS SCOLAIRES PAR SIG

RÉSUMÉ

La question de l'établissement des itinéraires d'autobus scolaires est de trouver un jeu d'itinéraires permettant d'offrir à ceux des élèves qui se qualifient un transport école-domicile, en tenant compte de la distance maximale, fonction de la classe de l'élève, que ce dernier peut parcourir à pied.

Cette application nécessite la manipulation d'un grand nombre de données à référence spatiale comme le réseau des rues et des renseignements sur l'élève. Le TransCAD, un SIG sur micro-ordinateur conçu pour les applications aux transports, a servi de plate-forme de gestion des données lors de la mise en oeuvre d'un système d'établissement des itinéraires d'autobus scolaires en milieu urbain.

Le système mis en oeuvre comportait quatre modules interreliés pour l'entretien des données et l'établissement des itinéraires, modules intégrés au système de menu de TransCAD. Le stockage de l'information était organisé en quatre niveaux de bases de données. Le système a été testé de façon empirique dans la ville de Guelph, avec des données fournies par le conseil d'éducation du comté de Wellington.

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1 Introduction

A frequently encountered problem in the provision of educational services is the problem of providing transportation for students to and from their respective schools. This problem has many aspects to it which make it significantly more complicated than standard vehicle routing problems.

Complicating factors are primarily due to that facts that (1) school students are not simple "packages" as in the case of pick-up and delivery of goods and (2) the service is publicly funded and therefore not profit driven. These factors impose several additional constraints and objectives on the routing problem as well as changing its structure. Additionally, a great deal of data are required in order to model the routing of school buses. Since the majority of these data are spatially referenced, a Geographic Information System (GIS) is appropriate as a data management and analysis platform.

This paper discusses first introduces the basic problem of providing school bus transportation services and defines a conceptual framework for modeling this problem, namely the Location-Routing Problem (LRP). Next, specific characteristics of the School Bus Routing Problem (SBRP) are introduced such as routing constraints, optimization criteria, streaming considerations, and the SBRP for urban areas. The next two sections discuss the implementation of a school bus routing system including a description of the program modules, the databases, the GIS package which was chosen for implementation. A brief overview of some results produced by the system are presented followed by some concluding remarks.

1.1 Problem Definition

For school boards in the Province of Ontario, the School Bus Routing Problem can be specified as follows: A population subset of spatially-distributed students must be provided public transportation services from their residences to and from their respective schools. The problem is to find a series of school bus routes which will provide this service for all eligible students. Student eligibility for school bus transportation is determined by board specific policies and is, in general, dependent upon grade, program, and the distance of a student's residence from the school. Additional restrictions are placed on the distance that a student can walk to and from the location where he or she is picked up and dropped off.

The nature of settlement patterns in rural and urban areas is quite different. These settlement patterns impose very different constraints on rural and urban school bus routes. In urban areas, students are modeled as demand points and can walk up to a specified limit to a school bus stop. In rural areas students are picked up at the intersection of their laneway and the road. The student demand is therefore modeled as being distributed along the road segment so that the bus must traverse particular road segments. Although it is also possible to model the school bus routing problem in rural areas [BCH91a] this paper concentrates on modeling the SBRP in urban areas.

School bus transportation is provided through the public sector and the evaluation criteria for measuring the suitability of the school bus routes are inherently multiobjective in nature. Due to political sensitivities within local boards of education, the school bus routes cannot merely be efficient in the sense of minimising the total cost of providing the service, but the must also seem to be fair and equitable.

1.2 Location-Routing Problems

In the SBRP it is necessary to locate facilities (the bus stops) and to construct the associated school bus routes to or through these facilities under given constraints. In this problem, the stop locations and the bus routing are interrelated decisions. Problems with these characteristics are known in transportation and operations research as Location-Routing Problems (LRP).

LRPs are organised in layers. For the problem of locating a series of depots and determining the delivery routes from the depot, the first layer is the factories which ship to the depots, the second layer is the depots, and the third layer is the customers.

Laporte [Lap88] defines a classification scheme for these problems based on the number of layers and the distribution mode, M_t, used by vehicles at a facility on layer t to deliver to facilities or users on layer $t+1$. The two distribution modes are:

$M_t = \mathbf{R}$ all trips from layer t are considered to be return trips (i.e. trips to and from a single facility); and,

$M_t = \mathbf{T}$ trips from layer t may be tours.

The whole system can be classified by the expression $\lambda/M_1/\cdots/M_{\lambda-1}$, where λ is the number of layers. The standard vehicle routing problem can be classified as a 2/T problem. For location-routing problems locational decisions must be allowed for at least one layer or it would be just a pure routing problem and tours ($M_t = \mathbf{T}$) must be allowed at least once or the problem becomes a pure location problem.

The urban SBRP can be classified as a 3/T/R problem. In this problem, layer one is the schools, layer two is the bus stops, and layer three is the students. Routing is the distribution mode between layer one and layer two (the school bus routes), and return trips is the distribution mode between layer two and layer three (students walking to their bus stops in the morning and back home in the afternoon). The locational decisions are made in layer two.

A LRP is composed of the following three subproblems:

1. facility location, which, in this case involves locating bus stops as facilities;
2. allocation of users (the students) to facilities (the bus stops); and,
3. vehicle routing.

These three components are interrelated and the separate optimisation of each subproblem individually will usually generate a suboptimal solution overall. As well, an integer programming formulation of any realistically sized problem will contain too many variables and constraints to be solved by an exact algorithm. Additionally, the network location-allocation subproblem and the vehicle routing subproblem [JP85] are both *NP*-Hard which indicates that there are no known polynomial-time algorithms to solve these problems. Therefore, solution methods for the LRP are based on heuristics. The heuristic best suited to the Urban School Bus Routing Problem (USBRP) is described and tested empirically against standard VRP heuristics in Bowerman et. al. [BCH91b].

2 Problem Characteristics

For School Boards in the Province of Ontario, the SBRP can be specified in the following manner: find a set of school bus routes which provide transportation to and from school for all eligible students. The eligibility criteria are based on distance from school and board specific policies.

This section serves to define the characteristics of the SBRP in the Province of Ontario. The limits that are placed on the school bus routes are introduced below and the specific criteria that can be used to evaluate the school bus routes are discussed.

2.1 Routing Constraints

Several different constraints are imposed on the school bus routes by board specific policies and the physical size of the school buses. These constraints include:

1. an upper bound on the number of students on each route (bus capacity);
2. an upper bound on the length (or travel time) on each route; and,
3. an upper bound on the total travel time (both pickup and delivery) that students can travel.

When checking the capacity of a bus the grades of the students occupying the bus are taken into consideration. Since students in the early primary grades are relatively small, these students are placed three to a seat while other students are placed two to a seat. Therefore, each early primary student counts as 2/3 units and each older student counts as 1 unit.

Another consideration is that school bus service is only provided to students who live outside a specified walking distance from their school or to students who have to cross a major highway to reach their school. Students who live closer than this distance, which varies by grade level, are expected to walk to their school and school bus transportation is not provided.

Finally, students are limited in the maximum distance that they can walk to a school bus stop. This consideration affects both the selection of potential bus stop sites and the assignment of students to bus stops.

2.2 Optimization Criteria

As well as having constraints set on the routes, criteria must be used to evaluate the school bus routes. Several criteria can be used to evaluate the quality of the solution of the SBRP. These criteria are:

1. **Minimise Number of Routes.** Since the capital cost is significantly larger per bus than the incremental cost over the year, the number of routes generated should be held to a minimum.
2. **Minimise Total Bus Route Length.** This criterion reduces the total length of the school bus routes.
3. **Balance Load.** Load-balancing involves minimising the variation in the number of students transported along each route.
4. **Balance Length.** This criterion involves reducing the variation in route lengths.
5. **Minimise Student Walking Distance.** This criterion minimises the total distance that students walk to and from their bus stops.

Note that the "first-on/first-off" policy on school bus routes implemented by many boards addresses constraint three in Section 2.1 as well as an equity consideration. This policy states that the first students to get on the bus before school in the morning must be the first students to get off after school in the afternoon. This attempts to equalise both the total amount of time any given student spends on the school bus over the whole day and the length of the school day itself, including travel. To address this policy, the school bus routes are designed, via the problem formulation, to begin *and* end at the school rather than just beginning *or* ending at the school.

2.3 Streaming Considerations

In Ontario, there are two parallel school systems in operation, the public and separate school board systems. The separate school boards serve Roman Catholic residents while the public system serves the rest of the populace. In addition, each school board is expected to provide many special services to the public. Three different streams of students can be recognised in the school system. Students can be part of the French Immersion stream which provides intensive education from Kindergarten through final graduation in Canada's other official language. As well, the provincial government requires the provision of education services to students with a wide variety of special needs. Finally, there are the "regular" students which do not fit into either of the above categories. Each stream of students can require the provision of school bus services.

Both French Immersion students and students with special needs introduce special considerations for school bus routing. Since relatively few schools provide a French Immersion program, these French Immersion schools may serve a larger attendance area than other schools. However, other than having different attendance areas, students in this program are treated as regular students.

School bus routing for students with special needs is extremely complicated due to the wide range of varying requirements of these students; it is assumed that manual methods are best used to take into account all these additional factors in the provision of transportation services. Consequently, this issue is beyond the scope of this paper and considered no further.

2.4 The Urban School Bus Routing Problem

In urban areas the student density per unit area is fairly high and the corresponding size of the attendance area for each school is relatively small. Each school bus route is designed so that it serves only one school. However, since the schools may have staggered starting and ending times, it is possible that a school bus may serve more than one route. The routes in the application described in this paper are designed so that the following activities occur.

Students are picked up at a bus stop that is within the designated walking distance of their residence. The school bus that picks them up completes visiting the rest of the bus stops remaining on its route and then goes directly to the school. In this system, each school bus route serves only one school. In the afternoon, the process is reversed and the students are dropped off at the bus stops where they were picked up in the morning.

Due to the high unit density of students in urban areas, the routes are relatively short. The length and total travel time constraints defined previously are not binding and are, therefore, dropped from the problem formulation.

Since there are a large number of factors that determine whether a certain site is appropriate for being a school bus stop, it is assumed that the potential bus stop sites are manually selected by an analyst. Factors affecting a site's suitability include characteristics such as traffic density, proximity to corners, and adjacency to public property.

The USBRP as described above actually involves two interrelated problems. One problem is the assignment of students to their respective bus stops and the second problem is the routing of the bus stops. As noted earlier, the USBRP can be classified as a 3/T/R type of LRP. Routing is the distribution mode between layer one and layer two (the school bus routes), and return trips are the distribution mode between layer two and layer three (students walking to their bus stops in the morning and back home in the afternoon). The locational decisions are made in layer two.

The use of a GIS is well suited to generating solutions to the USBRP. As described above, the USBRP can be thought of as being organised into layers. Each of these layers can be very complicated and contain a large amount of data, most of which are spatially referenced. In the next section, the organisational structure of a GIS is described. This organisation is based on layers of spatially referenced data.

3 Geographic Information Systems

In order to keep adequate track of the large amount of information used for school board planning and school bus routing, a Geographic Information System (GIS) is appropriate because of its spatial and nonspatial data handling capabilities. A GIS can be considered, in the most restrictive sense, as a program or suite of programs that is used to store, update, and analyse geographically referenced data. Broader definitions of GISs can include the hardware used by the system or even include all processes used from data acquisition, storing, checking, integrating, manipulating, analysing, and displaying spatially referenced data [Tay91]. GIS software, as well as providing data input and analytic functions allows for the production of maps and other graphic displays of geographic information. The usefulness of a GIS is most apparent when the application involves a quantity of data too large to be handled manually [Aro89] and when the application requires the integration of graphic and tabular databases.

Once the information has been input into a GIS, the data can be easily manipulated in ways that are too time-consuming or would be impossible to do using manual methods. Additionally, a GIS allows data to

be integrated from a variety of sources onto a common spatial reference framework. For example, a GIS can allow the information from municipal public works, engineering, and planning departments to be integrated so that each department has current information and can cross-reference databases that are held by other departments. GIS software can also be used as a tool to visualise spatial data and manage large quantities of spatially related information.

In general, a GIS stores locational data on geographic features as well as allowing for the storage of additional data on the characteristics of these geographic features. Many different "layers" or themes of information can be dealt with either individually or in user-defined combinations for the same areas on the Earth's surface. As well, most GISs include options for verifying the validity of data, such as ensuring that a road network is connected or making sure that polygonal areas are closed. Typical municipal applications can include land use regulation and planning, facility management and planning, election management, transportation planning, and vehicle routing [Aro89].

The TransCAD GIS package [Cal90] was chosen for use in developing an operational solution to the USBRP so that so that a user-friendly suite of analysis programs could be implemented for use by a school board. TransCAD is a GIS with extended capabilities for dealing with transportation information. It provides a large number of auxiliary programs for the analysis of transportation and operations research problems and is well designed for transportation planning and vehicle routing on a local scale. TransCAD can combine a series of spatial databases that refer to the same general geographical region to form an application. Some databases may only cover a subregion of the area of interest. These databases can be one of three different types:

Point A point database contains the coordinates and attributes for a set of points or nodes. The locations of customers, warehouses, or students are possible examples of point databases, at given scale. A point database can only be viewed with validity over a certain range of scales. At a large scale (e.g. 1:2000), a point would be more accurately represented as an area while at a small scale (e.g. 1:250 000) the point could disappear.

Line A line database is made up of both nodes and arcs. The nodes are where the line segments begin or end. Both the arcs and the nodes may have attribute data associated with them. An example of a line database could be a street or railroad network.

Area An area or polygon database is made up of regions that are defined by a series of connected boundary edges. Each area may have attribute data to describe its characteristics. The attendance and development areas within a school board area could be defined as a polygonal database.

Each of these databases can be interrelated spatially. For example, it is possible to find all students within a given school board development area, or to find all attendance areas that a certain road passes through.

It is possible to define a special network file from a line database. This file contains just a limited subset of the information from the line database. The geographical information is removed from the database and condensed into nodes, arcs, and simple numeric values. This file allows the line database information to be accessed by other software outside of the TransCAD environment.

One final significant capability of TransCAD is its procedure interface. This allows the user to include new procedures that act upon the geographical data and display the results of these procedures. Using this interface, a user, such as a school board transportation planner, can, for example, select certain intersections on a street database to be used as potential bus stop sites, run the school bus routing module and display the resulting routes directly on the street network after processing is completed. Included with TransCAD are hard-coded procedures for finding the shortest path between nodes on a network, for traffic assignment, for generating solutions to the VRP using the Traveling Salesman heuristic, for spatial interaction modeling, for location/allocation modeling, and for geocoding. This suite of procedures far exceeds those provided by other packages, such as the Network module of ARC/INFO, and serve to make TransCAD an ideal companion package to the development of the application described in this paper.

A critical factor for the use of a GIS is the acquisition and importation of data into the GIS [Aro89]. In order for a GIS application to be successfully developed a large amount of information must be collected. The next section discusses the implementation of the school bus routing system in TransCAD.

4 Implementation

The school bus routing system was implemented on a PC Compatible 386 microcomputer running at 20 MHz and with a numeric coprocessor. All application programs for the USBRP solution described in this paper were written by the first author in the 'C' language using Microsoft 'C' version 5.1.

The system was written as a series of four programs called within the procedure interface of the TransCAD program. Additionally, the db_VISTA III database management system [Rai90] was used to access the various TransCAD databases. db_VISTA was chosen since it is the database management system that TransCAD uses to organise its databases.

The four modules that were implemented as part of the USBR system are: the marking of French Immersion students modules, the attendance area and node assignment module, the distance table creation module, and the school bus routing modules. These modules were designed and implemented by the authors and integrated into TransCAD. The next two sections describe the TransCAD database information used by the implementation and the functionality of each module of the system. The overall structure of the implementation is illustrated in Figure 1. Further details on each module are available in Bowerman et. al. [BCH91a].

4.1 Data

The information required for the school bus routing system is contained in the following databases, and school assignment tables. This section describes the purpose of each database and table.

The Street Database This database is a line database that contains the address-matched street information for the area under study. The database is composed of two layers: the arc (street) layer and the node (street intersection) layer. Information stored in this database includes a node usage indicator, street name, arc length, and address ranges. As well, a relationship between the street node and arc segments is set by TransCAD so that it is possible to identify all street segments that end at a particular node and at which nodes a street segment starts and ends.

School Database This is a point database that contains information about each school including school number, name, and address.

The Attendance Area Database This database is an area database which serves to partition the city into attendance areas or development areas. There are very few user accessible attributes of this database. Most of the information is a geographically defined set of boundary edges.

The Student Database The information contained in this point database consists of one record for each student. Information includes student address, grade, program (French Immersion, regular, etc.), school number, nearest node, bus stop node number, route number. Many of the attributes in the student database are set by running the appropriate program from the procedure menu of TransCAD.

The School Assignment Tables These tables contain the information necessary for determining which school a student attends. There are two student assignment tables, one table for students in the regular program and another for students in French Immersion. Each of these tables are structured identically. Each row in the table, indexed by the attendance area number, represents the school assignment for a particular attendance area. There are 14 entries in each row corresponding to the 14 grade levels

(Kindergarten to OAC). Each entry consists of the school number for that particular combination of attendance area and grade.

These databases and tables were integrated with a series of modules designed to access, maintain, and utilise this information to generate school bus routes. The modules are described in the next section.

4.2 Modules

The school bus routing system is made up of a set of four interrelated modules (Figure 1). Each of these modules handles a different part of the entire school bus routing process. These modules are described as follows:

Marking of French Immersion Students This module takes a French Immersion Student file and marks every matching record in the student database as being in the French Immersion program.

Attendance Areas and Node Assignment Once the program for each student is appropriately determined and entered into the student database, this module is executed. The purpose of this module is to assign students to the nearest street intersection and to determine which school they should attend. Once all students have been processed, the student demand tables for each school are written out. After this module has been executed, the distance table creation procedure can be executed.

Distance Table Creation The calculations of distance along a network can be a computationally intensive operation, particularly for large networks. In order to speed up the execution of the school bus routing module, the distance calculations were separated into a standalone module. This module calculates the shortest path along the network from the school or each potential bus stop site to each other bus stop site (or the school) and every node in the student demand table for this school.

School Bus Routing This module takes the student demand table generated by the node assignment program and the distance table generated by the distance table creation module and generates school bus routes for a specific school.

These modules have undergone initial testing using data for a school in the City of Guelph. A brief discussion of this testing is presented in the next section.

5 Results

Testing of this school bus system was performed using data provided by the Wellington County Board of Education. John McCrae P.S. was chosen as the school to be used for examining the performance of the school bus routing system. This school is located in the south end of the City of Guelph and provides a regular program from Kindergarten to Grade 6 for students within its home attendance area and a French Immersion program for students in Grades 4 to 6 from seven attendance areas and 5 development areas in the city. A total of 307 students were assigned to this school of which 151 were in the regular program and 156 were in French Immersion.

The school bus capacity was set so that the maximum weighted demand on a bus was 50. Out of the 307 students assigned to the school, 138 lived further than the maximum walking distance to the school and thus qualified for school bus transportation. All these students were in Grades 4 to 6 (since they were in the French Immersion program) hence the total weighted demand was 138. Three school bus routes were required and the balanced load on each school bus was 46 students.

The results of a sample run of the school bus routing software is illustrated in Figure 2. This map shows the portion of SW Guelph that is serviced by John McCrae P.S. with the student assignments to their respective bus routes, the bus stop selected and the school bus routes. Note that on the map the sections

of the route going from the school to the first bus stop and from the last bus stop to the school have been omitted for the sake of clarity.

We also note that in addition to solving optimally the school bus routes for candidate students, the USBR application developed under TransCAD provides the school board with powerful reporting capabilities. Bus routes with road distances, street names and directions, and student pick ups at each stop can very easily be printed for use by bus drivers, school board trustees, parents and teachers. Moreover, schools can manage data on bussed and non-bussed students very easily with the software.

6 Concluding Remarks

The school bus routing system discussed in this paper implements many important features. The USBRP is a complicated location-routing problem that embodies features that make it ideal for implementation with a GIS capable of handling network applications. The correspondence between modeling the USBRP as a 3 layer LRP and its implementation in a GIS-based computing environment is quite strong.

The features of GIS are of significant use in implementing school bus routing systems. For example, the management of an address-matched street network is a natural application of GIS. In determining the appropriate school for students to attend, the utility of matching the home address of a student against the street network and thus finding the location of the student's residence and the nearest street intersection allowed for the creation of the spatially distributed school bus information. This information was then used as an input to the school bus routing process.

Additionally, the choice of TransCAD software, with its special features, in preference to other commercially available GIS packages is confirmed by the application. Of particular use is the well designed procedure interface which allows the developer to integrate a specialised application within the program. This interface allows a series of menu driven modules to be executed from within the TransCAD package and also allows for the graphical results to be plotted by TransCAD. Thus the data management and interface capabilities of TransCAD can be combined with specialised modules for the generation of school bus routes to form a cohesive and easy to use system. Furthermore, the school bus routing system could easily be integrated into a much larger school planning system based on a GIS (see Fuick [Fui91] for example). The data used for this planning system could be used as input to the school bus routing process and the board could achieve integration of the entire process.

Additionally, the design of school bus routes could be made part of the planning process to include, on occasion, the testing of alternate attendance areas. After the attendance areas are redefined, it would be possible to generate corresponding school bus routes and allow alternative choices to be costed. The output of this attendance area system would be the attendance area boundaries and the school assignment table needed to generate school bus routes.

Acknowledgement

The authors would like to thank the Wellington County Board of Education, in particular Rob Fuick and Dennis Cuomo, for providing us with data and insights into the considerations made in planning school bus routes.

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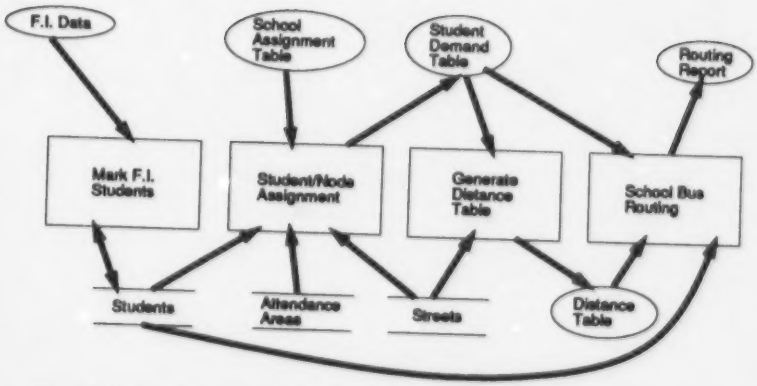

Figure 1: Module, data base, and file interrelationships in the school bus routing system

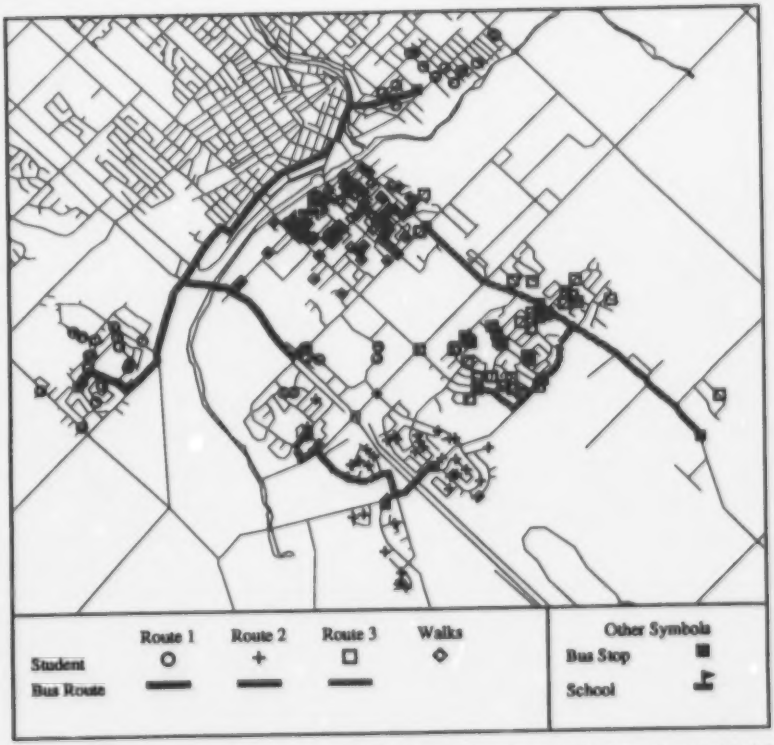

Figure 2: Student Assignments and Bus Routes for Sample Execution of School Bus Routing Module

Privacy and Profits: Marketing Data Products and Services in the Context of a Strategic Alliance

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Abstract

The government of Ontario, Canada and a consortium of private sector companies have entered into a strategic alliance for the purpose of automating the provincial land registration system and establishing a vehicle for marketing value-added products and services. The strategic alliance embodies a tension between the traditional public service role of government as regulator and registrar, and the profit motive of private enterprise. No more clearly is this tension evident than in the area of access, use and pricing of data and related services. This paper explores a range of data issues encountered by the partners in the early negotiation process and later by Teranet, the strategic alliance corporation.

Le secret et les profits: La commercialisation de produits et services informatisés dans un contexte d'alliance de stratégie

Résumé

Teranet Land Information Services Inc. est une compagnie de services informatiques formée en tant qu'alliance de stratégie entre le gouvernement de l'Ontario, du Canada et un consortium du secteur privé. Teranet a pour mandat d'automatiser le système d'enregistrement des terres de la province et de mettre au point et commercialiser des produits et des services informatiques à la valeur ajoutée. L'alliance de stratégie sous-entend une tension entre le rôle traditionnel du gouvernement en tant que régulateur et greffier des services publics et le motif de profits qui est le propre de l'entreprise privée. Cette tension n'est pas plus nettement évidente que dans le domaine de l'accès, usage et établissement du prix des données et des services connexes. Cette communication explore une gamme de questions légales et politques que les partenaires ont éprouvée au moment d'établir la corporation et par Teranet elle-même dans la formulation de ses stratégies commerciales.

INTRODUCTION

On May 29, 1991, Teranet Land Information Services Inc. joined the small but rapidly growing number of companies having as its intangible stock in trade geographic information.

Teranet is set apart even within this relatively small industry by virtue of its pedigree. Teranet is the product of a unique partnership between the Government of Ontario, Canada and group of private sector firms represented by an Ontario-based consortium, Real/Data Ontario Inc.

Teranet's raison d'être is threefold:

1. to automate and enhance the province of Ontario's land registration system based on the POLARIS technology developed by the provincial government. The automation of the land registration records - an eight year program - includes conversion of registry properties to land titles, creation of a computerized title index and development of a digital property map base.

2. to develop an information utility to manage the land registration databases and other information, and serve as the communications hub for remote access to the system; and

3. to market its expertise, systems, and applications within Canada and internationally. New services will be developed over time in response to market demand.

The nature of the partnership and the ultimate form of the company itself were shaped through a long process of dialogue and negotiation stretching back to 1987. The Teranet strategic alliance is a true partnership in which responsibilities, financial contributions, risks and returns are fairly shared - a win-win situation for the two shareholders.

Teranet embodies an unique business model that moves both partners into uncharted waters. For the government, which has primarily a public service and regulatory focus, Teranet represents a paradigm shift into the world of free enterprise. For the private sector shareholder, Teranet is a marked reorientation from a pure contractual or service delivery focus.

Teranet was established to take full advantage of the synergy of the partners' skills, experience and resources. Each partner has made a significant contribution to the partnership and in return reaps benefits not attainable through traditional approaches.

The government shareholder gives the company a sense of stability and accountability, and provides to the venture the POLARIS system and expertise and an equity investment. Government benefits from a reduction in project costs, increased revenues, accelerated

implementation of an enhanced POLARIS system, reduced internal operating costs and province-wide industrial development benefits of employment and skills development.

The private sector participation provides Teranet with business skills, a marketing network and equity. The benefits to industry include a financial return, long term contracts that stabilize a traditionally cyclical industry, transfer of government expertise and the opportunity to participate in international markets on the strength of the Ontario experience.

Perhaps most significantly, both partners have a real opportunity to redefine the business relationship between industry and government in the province of Ontario.

Through the enhancement of POLARIS, Teranet will provide a service with improved functionality. Lawyers will no longer need to travel to a land registry office to search records and register documents. Real estate brokers and appraisers will have a wealth of accurate, timely information at their finger tips. The digital property map will be the basis for a broad range of planning, routing, administration and facilities management applications.

Since incorporation in May, a number of start up activities have occupied the company:

- managing the transfer of the POLARIS implementation function including the transfer of staff from government to Teranet;
- defining domestic and international market opportunities;
- acquiring accommodation;
- preparing a five year business plan covering marketing, communications, implementation, human resources, technology and R&D; and
- fostering a corporate culture.

The logistics of corporate start up have strained scarce resources. Teranet's business is a massive undertaking involving computerization of the records for 4.2 million properties and developing the capability to provide real time, on line province wide access to the databases. The Teranet vision requires extensive technical enhancements to create a true GIS and deliver a range of value added services across a spectrum of clients.

CRITICAL FACTORS SHAPING TERANET'S DATA MARKETING APPROACH

Teranet is in the information marketing business. Development of the strategy to manage and market data and value added products and services is a critical component in achieving Teranet's vision. The data marketing efforts of Teranet are now being shaped by a number of critical environmental factors.

By way of analogy, these factors define the sides of a box within which the Teranet data marketing strategy rests. Teranet must effectively respond to or capitalize upon these factors to achieve its full market potential.

These factors are, of course, moving targets and will be constantly revisited in the ongoing process of business planning.

The four sides of the box are:

1. The Nature of the Partners and the Partnership
2. The Nature of the Land Registration System and Data
3. The Impact of Automation
4. The Business Environment

1. Nature of the Partners and the Partnership

The relationship between public and private sectors indeed provides an opportunity to capitalize on the respective strengths of the partners. It has also presented difficult challenges - as might be anticipated in any relationship (business or otherwise) that requires a meeting or blending of cultures.

Painting a slightly libellous caricature of government and industry may help to illustrate the cultural differences inherent in government/industry partnerships. Below is a list of some familiar cliches used by (or in reference to) the respective parties. These contrasting phrases illustrate some fundamental differences in perspective and philosophy. Many of these distinctions are, however, more perceptual than real, but are influential none the less.

FREE ENTERPRISE	**VS.**	**GOVERNMENT**
risk taking		risk averse
proactive		reactive
entrepreneurship		accountability
enhanced service		universal service
access to information		protection of privacy
self regulation		government regulation
guidelines		laws
network		hierarchy
market responsive		mandate fulfilment
clients/customers		public
dividends		consolidated revenue fund
profits		revenues
creative financing		budget constraints
market rates		cost recovery
price increases		tax hikes
the bottom line		the public good
equity financing		debt financing
prices		taxes

Recent events are, to some extent, reducing the gap between the traditional perspectives. In the current economic climate, governments are keenly interested in finding creative approaches to service delivery - delivering services without increased taxpayer burden.

Private industry is recognizing the inherent profitability of being good corporate citizens, whether it be in employment practices, environmental sensitivity or, closer to home, information marketing.

The government of the day is a ready target for political pressure by the media and the public. The involvement of government as a partner has, by extension, brought Teranet into the public forum.

Teranet's first hand experience with such scrutiny came in the form of a partnership profile in a fall episode of the CBC program Fifth Estate. Although most impartial observers dismissed the show as a conclusion in search of evidence, it still caused a significant drain of time and energy of the management of the company during filming and following its presentation.

The profile and nature of the venture dictates certain sensitivities. In response, Teranet has set itself up as a company that operates with the highest order business ethics and consideration for its shareholders, clients, suppliers and employees. This is by nature an exercise in balancing various, sometimes conflicting, interests. Public accountability, however, is an essential touchstone for all business strategies, including data marketing, access, use and pricing.

The precepts of accountability and high ethical standards are important for any successful business. For Teranet they are essential.

2. The Nature of the Land Registration System and Data

The nature of the land registration system and the data contained within it are factors that shape Teranet's information policy.

First, land registration in Ontario is a monopoly business which, since the eighteenth century, has been the responsibility of the provincial government. Individuals wishing to register their interests in land - the only way to ensure that their rights are protected - must use the only game in town.

In recognition of the monopoly nature of the service, the partnership legal agreements dictate that government continues to operate the land registration system and owns the land registration data. Government controls registration and search fees and approves the new value added products and services. Teranet holds an exclusive 10 year licence to manage the databases and deliver raw data and value added products and services to users. Users will be offered a choice: basic services in a land registry office, or remote access and value-added products and services through Teranet.

Second, although the land registration databases contain both personal and non-personal information, of necessity the system is fully open to the public. Anyone may walk into a land registry

office and, upon payment of the proscribed fee, examine any records on file.

This environment of personal information maintained in a public domain presents a dilemma for the company. Resolution of the issue requires a fine balancing of access and privacy, two often competing value systems. After all, privacy in its purest sense precludes access and access in the extreme eliminates privacy.

Privacy legislation focuses on preventing the use of information as well as unfair or unwarranted disclosure. However, over the last ten years there has been a change in the dialogue over access and privacy with the discussion shifting to the side of the equation dealing with data access.

Traditionally government information access policy has focused on the concept of "open government and accountability". Access to information in this context is treated as one of the cornerstones of a free and democratic society.

In contrast business focuses on information access as part of the competitive advantage - a source of information on the marketplace and competitors (leverage) and a commodity in its own right (profitable asset).

Teranet is bound by the terms on information marketing that are spelled out in the partnership legal agreements. These terms are, however, only the starting point. To illustrate, Lotus Corporation recently proposed to offer a CD-ROM product called Marketplace containing the names, addresses, shopping habits and the estimated incomes of some 120 million American consumers. In response to a public backlash focusing on privacy, data quality and timeliness Lotus pulled the product offering.

The Lotus Marketplace product was "legal".

In recognition of such public sensitivities, Teranet will be guided by principles of quality and accountability. Yes, information will be more accessible - but in a manner that emphasizes quality in data and service. Teranet will have a customer service focus and a service orientation.

For the company, the consequences of improper actions are grave. If Teranet does not manage the asset properly, government, in its capacities as shareholder, party to the legal agreements and licensor, will react appropriately. Failure to behave appropriately could trigger government veto of new services with resulting financial loss. Ultimately, the company could lose its exclusive licence to the land registration databases.

3. The Impact of Automation

Computer information systems are the alchemist's dream - making a thing of valuable out of something ubiquitous. Rather than

creating gold from lead, they create gold from bits of data strung together and manipulated through the marvels of computer technology. Unlike traditional assets - like land, capital or labour - data is expandable, transferable and reusable.

Storage of information in electronic form is not in itself a contentious issue. Nor is the data which is in basic form value neutral. Rather, the Lotus experience illustrates that the controversy surrounding automation has been caused by those who creatively build on improved access to information using data manipulation techniques such as computer matching, networking and profiling. The issues surrounding the integration of databases points out that the "whole" can be considerably more controversial than the sum of the parts.

As Teranet seeks to add additional data sets to its product offerings, these potential pitfalls must be identified and appropriately managed.

In the minds of the general public, automation is equated with accuracy. This expectation of accuracy plus the difficulty in predicting the ultimate use of the data may result in a greater risk of liability to the information provider than would be the case in a manual environment. Like the industry itself, computer and information law is still in its infancy - the rules are still being written.

Dealing with the automation pitfalls is a part of the company's overall Total Quality Management strategy. To paraphrase the President of Teranet "we are not a mailing list company". While this statement is not intended to criticize firms filling this particular market niche, it does point out that just because Teranet "can" do something does not mean it "will".

4. The Business Environment

Information is being touted as the cornerstone of the next global economy. In the new information marketplace, government often finds itself functioning in a number of roles including "licensor", "regulator" and "competitor".
This interplay of roles is not popular with the information sector, which has been lobbying for a greater share of the information pie including greater access to data, changes in copyright and less government regulation. The information industry, in recognition of the concerns of both government and the public, has been vocally supportive of self regulation.

Teranet is a new participant in this emerging economy. The company will pay heed to the positions taken by the information industry and will take its place as a vehicle for constructive change. As matters of principle, Teranet focuses on conveying its commitment to integrity, accountability and quality.

Teranet endorses a continued government involvement in the industry. The unprecedented pace of social and economic change brought about by the "information revolution" leaves government with legitimate concerns about the information marketplace.

At a micro level, government has a very important role in Teranet. Government requires a certain comfort factor regarding its stewardship over corporate information assets. Government is well aware that it could ultimately be held accountable for the quality of the business decisions involving the dissemination of its information assets. The message sent by Teranet and its partners is clear - by creating the company, government has not sold its soul.

At a more pragmatic level, the reality of Teranet's need to generate revenues to finance continued automation dictates that the high activity parts of the province are the first to be automated. Financial considerations also must be considered in the planning of new services.

CONCLUSION

Development of corporate strategies to manage data and information assets can be achieved in two ways. The first approach uses a strict application of the "rules" and looks at **what can be done** in the information marketplace. The second approach considers **what should be done** using the "rules" as a starting point. The first approach is the classic model of action/reaction whereas the latter is more proactive in nature.

It is this second strategy that Teranet is pursuing, recognizing that it is not an easy matter to balance the spectrum of environmental issues facing the company at this early point in its corporate existence where "time is of the essence".

What happens when reality conflicts with intention? Those times are expected. Moving targets are a business reality and the company's responses will be carefully watched by the shareholders, the media and a myriad of system users.

Teranet Land Information Services is in the information business for the long term. Teranet will continue to build on the synergy of partnership - the blending of skills and resources to create a whole that, like information itself, is greater than the sum of the parts.

RT-TREE: SPATIOTEMPORAL INDEXING FOR DYNAMIC LAND DATABASES

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Abstract

Land subdivisions are important events in land information systems. In a land information system the subdivision path over time needs to be maintained. However, the nested spatial objects due to spatial subdivisions cause problems for database indexing based on objects' locations. These contiguous spatial objects can introduce large overlap index regions, thus leading to inefficiencies. One of the challenges in LIS/GIS research is to develop index structures that effectively support land database management. One indexing approach is the RT-tree. The RT-tree approach is developed on a portion of the database that forms part of the Automated Canada Lands Information System (ACLIS). A time-stamping method is adopted for incorporating time-oriented data models and for improving access. This research suggests that the RT-tree should be investigated as an effective index structure for geographic/land databases with dynamic updates.

RT-TREE: INDEXATION SPATIOTEMPORELLE DES BASES DE DONNÉES DYNAMIQUES SUR LES TERRES

RÉSUMÉ

Les lotissements sont importants dans les systèmes d'information sur les terres. L'évolution des lotissements dans le temps doit être suivie. Toutefois, les éléments spatiaux bouclés à cause de lotissements dans l'espace soulèvent des problèmes d'indexation des bases de données fondées sur la position des éléments. Ces éléments contigus dans l'espace peuvent amener d'importants chevauchements des régions index, ce qui entraine des pertes d'efficacité. Un des défis de la recherche sur les SIL/SIG est de mettre au point des structures d'index qui apportent un soutien efficace à la gestion des base de données. Une approche d'indexation est le RT-TREE. Ce dernier provient d'une partie de la base de données qui constitue le Système automatisé d'information sur les terres du Canada (SAITC). Une méthode d'indication du temps est adoptée pour intégrer des modèles à données chronologiques et pour améliorer l'accès. Cette recherche indique qu'il faudrait étudier le RT-TREE comme structure d'index efficace pour les bases de données géographiques et de données sur les terres avec mises à jour dynamiques.

1. Introduction

A Geographic Information System (GIS) is an integration of multiple spatiotemporal data processing disciplines. The purpose of GIS research is to develop a powerful set of tools for collecting, storing, retrieving, displaying and updating spatial and/or temporal data from the real world. A reasonable future goal for GIS development is that they should be capable of tracing and analyzing changes in spatial information over time (Langran, 1989 : 216). The development in spatial access methods (SAMs) represents a considerable body of work within the field of study on large spatial databases. Although this is not specifically intended for GIS applications, it could be used to develop more intelligent geographic/land information systems capable of handling complex geographic data such as a image database or polygonal map manipulated in a dynamically changing environment.

In geographic data processing, spatial subdivision and aggregation are frequent and important events which represent spatial objects changing over time. The spatiotemporal process of land subdivision is at the heart of the way in which land is managed. The rectangular nature of land parcels makes an approach based on the R-tree intuitively appealing for spatiotemporal indexing in land database systems.

Guttman (1984) proposed a R-tree as a dynamic index structure for spatial searching. The R-tree, R^+-tree (Sellis et al, 1987), R^*-tree (Beckmann et al, 1990), and the Cell tree (Gunther, 1988) are the most recent spatial access methods for supporting effective indexing. These methods have been studied extensively. However, incorporation of these methods with temporal geographic analysis is right at the beginning of exploitation. Xu et al. (1990) suggest use of RT-tree, an improved R-tree, to index spatiotemporal databases such as database for urban growth study. The idea is attractive not only because Guttmann's R-tree is a very promising method (Faloutsos et al, 1987), but also the combination of R-tree with temporal information will further increase the power of the indexing. The significant differences between Guttmann's R-tree and this RT-tree are that indexing on nested objects due to spatial subdivisions is a particular focus, and the temporal factor is added.

2. RT-tree Spatiotemporal Indexing for GIS/LIS

Spatiotemporal indexing support implies two functions :

(1) being able to trace the chain of legal and field survey operations and/or land use subdivisions;

(2) being able to update an object's index location and to rely on the system to update locations of objects that depend on the updated object.

Spatial objects change their shapes at the time of subdivision in a way that newly created objects completely nest within the old one resulting in overlapping indices. The temporal information in the RT-tree can be exploited to speed the indexing process and help maintain the path of spatial changes. A date-stamping method is utilized where to one timestamp, the indexing insertion operation is same as that of R-tree, but in subdivision circumstances, the node identifier (node-id) and timestamps are carefully set so that the semantically meaningful relationships between parent and children objects are distinguished at the index family tree. With the help of timestamps, these changes across time can be represented and retrieved on relevant branches of the RT-tree.

2.1 Node Split Strategies

This RT-tree solves for index containment by upgrading old node-id of leaf entry to the parent node so as to create a historical path (family tree) of the subdivision. The subdivided object has a timestamp interval from the object's create time through to the time when it is later superseded by new object instances. It has a pointer linking to its sub-units or children. Leaf entries have timestamps different from that of parent node in that they are timestamp items rather than an interval. The family tree is built up so that the real object-id at internal level (i.e non-zero or non-negative) implies that the object exists within a period of the timestamp interval and subdivided by its pointing children objects.

To add a new entry to a full node containing M entries, it is necessary to divide these M+1 entries into two nodes. The node splitting algorithm is crucial to how much overlap exists in the resulting rectangles (Greene, 1989). This RT-tree uses the following method to find splits: the algorithm first calculates the centroid of the M+1 entries, then the distances between each pair of centroid; the largest distance is computed and the corresponding entry indices of the two ends of the line are recorded; in addition, the angle of the line to the X axis is also calculated; hence, the splitting axis is chosen in a way that if the angle is less than 45 degree the splitting can be performed along X axis, and verse versa. The threshold for the splitting simply uses the average on that splitting axis. Poor performance can be avoided by appropriate boundary conditions.

2.2 Construction of RT-tree

The RT-tree has three types of nodes:

1) a node being a root of the tree;

2) a leaf node whose pointer is an object identifier (or tuple identifier in a relational database) to the specific location of the object stored in a database; and

3) an non-leaf node with pointer pointing to its children nodes.

Leaf nodes in an RT-tree have index entries of the form

(*leaf-node-id, MBR, timestamp, tuple-id*)

where *leaf-node-id* is equal to *tuple-id* referring to a tuple in the database, *MBR* is a minimum bounding rectangle of the spatial object in the form

$[x_{min}, x_{max}, y_{min}, y_{max}]$,

and *timestamp* is a date the object is stamped in the form of year/month/day. An non-leaf node is created in the form

(*non-leaf-node-id, MBR, timestamp, child-pointer*)

where *non-leaf-node-id* and *timestamp* need to be particularly set under the index contains which is different from that of general covering nodes in the domain of node-identifier and timestamps. An *non-leaf-node-id* can be a zero, negative, and a list of positive tuple identifiers, *MBR* covers all entries in the lower node's entries, *timestamp* can be a zero and a time interval of the form (t_i, t_{i+1}) for a node created at t_i and subdivided at t_{i+1} (e.g. [1962-01-01, 1973-01-01]), and *child-pointer* is an address of a lower node in the RT-tree. Table 1 describes the main functions of our RT-tree implementation. Table 2 provides detailed description of the algorithms that are implemented in the functions.

3. RT-tree Implementation on the PFIS Database

The Property Fabric Information System (PFIS) is part of the Automated Canada Lands Information System (ACLIS) and manages three types of information: points, lines and polygons corresponding to the three components of the survey fabric: monuments, boundaries and parcels (Robinson, 1989). The PFIS database has to deal with 125,000 land survey records, each with up to 50 attributes. Periodic updating occurs whenever a new survey plan is made at a specific date. *The PFIS must retrieve the forward and backward cadastral parcel history based on a specified cadastral parcel* (Egesborg et al, 1990).

PFIS may be thought as a LIS expanding the relation data model to incorporate some aspects of temporality. Land parcel records in PFIS contain fields that note dates of survey plans. A plan subdivision is assigned a number at the time of registration. The plan number is an unique attribute involved in all PFIS searches.

In the On-shore Plans (ONPL) table, the date at which parcels were surveyed/collected is recorded as an attribute of a plan. In Survey-Parcel (SURVPCL) table, parcel identifiers are the primary keys

whereas plan number is used as time-stamped attribute to parcels corresponding to a survey time to these parcels. Historical records are stored in Polygon-Parcel (POLYPID) table with link to TOPOLOGY table. For example, parcel 23 was surveyed in plan 52033 and superseded by a set of subunits in plan 58768. In SURVPCL table, parcel 23 is still one of tuple identifiers of plan 52033 but with superseded status "Y". Corresponding to this parcel identifier, parcel 23 is no longer referred to as being part of present survey fabric in TOPOLOGY table and is described by reference to the numbered superseded polygon labels in POLYPID table. Topology is always defined by the arc network which corresponds to present survey fabric.

3.1 PFIS RT-tree

The PFIS RT-tree was built with the assumptions:

Assumption 1: No different plans are recorded or surveyed on the same day in the same spatial extension, thus, timestamp of plan can be unique to the date on which the plan was made.

Assumption 2: If MBR of a spatial object completely contains the MBR of a new spatial object, we assume the previous object is being spatially subdivided by the new comers. This is based on the fact that to one layer of cadastral/land database, there is no overlap between parcel units.

Assumption 2 implies that the RT-tree developed here is particular for spatial databases having hierarchical data structure over time but not at one layer/time. In other words, objects at the same layer of database can not overlap each other. For other applications, Assumption 2 may not be true.

When considering the encoding multiple layers of spatial information into the same RT-tree, one can declare timestamp to be an array instead of an item for the case that one spatial object was involved into different types of layer/event if relevant attributes are time-stamped. What is needed in this RT-tree is extending the timestamp array to include all relevant attribute values.

The final RT-tree for our portion of the PFIS database is shown in Figure 1. The leaf level of the RT-tree is the state of the existing database for facilitating the search of present survey fabric. Historical changes in a defined query window can be retrieved from the related branches of the RT-tree.

3.2 Handling Multiple Splits in the PFIS RT-tree

In PFIS it is conceivable that one parcel may be split more than once. For further explanation of strategies developed in this work, a multiple split case is made up in which parcel 125 was split into parcel 2000 and 2001 in one plan, then parcel 2001 was split into 20010 and 20011 in another time. The corresponding spatial partition and the RT-tree are shown in Figure 2.

When multiple split occurs on a spatial object, the first step is to separate this object from the other entries, then upgrade the node-id to the parent entry by expanding the node-id to a list to include the upgraded one, e.g. node 23' changes the id from 23 to (23, 125) with pointer pointing to the containing children 2000 and 2001. Similarly, further split treatment on 2001 is that the parent node-id becomes (23,125,2001), the pointer points to 20010 and 20011. Distribute the remaining entries into a sibling node which needs least enlargement to include them. The strategies presented for multiple split have not significantly increased the height of the tree as well as the number of nodes. However, search for all subunits of an old split parcel may need to go through more sibling branches.

4. Concluding Remarks

The RT-tree developed in this research was implemented in C on a Sun 4/110 Unix workstation. Testing of the RT-tree was conducted on a portion of ACLIS-PFIS database. Using this "real world" testbed, the resulting distribution of indices follows expectations. In addition, the order of the input is changed to test the effect. It was shown that the RT-tree performance is not input order dependent. However, a different order of input will build different structures of RT-tree. An optimized order of input will correspond to an efficient retrieve performance. This research suggests that the RT-tree should be investigated as an effective index structure for geographic/land databases with dynamic updates and in changing environment.

5. Acknowledgments

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Table 1. Main Functions of RT-tree Implementation.

Function Name	Description
RT-tree	a main function to get index records, perform calls of several main operations such as insertion of indices into RT-tree, deletion, and so forth necessary to the database;
Insert_RT	to insert a new entry into leaf level of an originally empty RT-tree. A set of processes for construction of a RT-tree are performed in this function;
Non_Leaf_Insert	to insert an entry at non-leaf level including a series of subfunction calls such as Choose_Entry, Check_Contain, and Contain_Insert;
Contain_Insert	to insert an entry which is completely included in an existing entry;
Contain_Adjust	to build a family tree created during subdivisions;
Choose_Leaf	to choose a leaf node to place a new entry into it;
Choose_Entry	to choose an entry whose bounding rectangle needs least enlargement to include a new entry;
Check_Contain	checks the coordinates of bounding boxes to see if the one index box is wholly inside the other, that is, whether the following conditions are satisfied: where X and Y are coordinates of existing covering rectangles, and x and y are that of a new index entry;
Node_Split	to separate M+1 entries into two RT-tree nodes;
Get_MBR	to calculate the Minimum Bounding Rectangle (MBR) of a node, usually, it is needed when a new entry is inserted or an old node is split.

Table 2. Descriptions of Main Functions and Algorithms.

Main Function: RT-tree

- **IRT1.** Invoke **Open_File** to access to index file.
- **IRT2.** Invoke **Make_Entry** to create a new spatiotemporal index entry E.
- **IRT2.** Invoke **Insert_RT** to insert E into current RT-tree T.
- **IRT3.** If T was split having a sibling node T′, invoke **Get_MBR** to adjust the new covering MBR of T, and create a new root TT whose children are T and T′.
- **IRT4.** Set TT to be T. Repeat from **IRT2** when next new index entry is inserted.

Algorithm Make_Entry

- **ME1.** Read data from an index file.
- **ME2.** Formats the spatiotemporal information to a leaf index entry E.
- **ME3.** Return E.

Algorithm Insert_RT

- **IRT1.** Invoke **Choose_Leaf** to select a leaf node T to place E.
- **IRT2.** Invoke **Check_Contain** to check if there is an entry EE in T spatially containing E. If yes, invoke **Contain_Insert** to place E as a child of EE, upgrade EE to be a parent node. If no spatial containment, then if T has room for E, install E, otherwise, invoke **Node_Split** to separate all entries in T and entry E into two nodes T and T′.
- **IRT3.** Create a parent entry *tempentry* for T′.
- **IRT4.** Return T, *tempentry*, and T′ (T′ can be "null" when no split occurs).

Algorithm Choose_Leaf

- **CL1.** If T is a leaf, return T.
- **CL2.** If T is not a leaf, invoke **Non_Leaf_Insert**.

Algorithm Contain_Insert

- **SI1.** Create a new node *tempnode*, install E.
- **SI2.** Upgrade entry EE that contains E to be a parent entry *tempentry* of E, set pointer pointing to the *tempnode*.
- **SI3.** Set *tempnode* to be T′, return parameters T, T′ and *tempentry*.

Algorithm Non_Leaf_Insert

- **NLI1.** Invoke **Choose_Entry** to select an entry C in T whose rectangle needs least enlargement to include E.
- **NLI2.** If selected entry C is a regular covering rectangle identified by its node-id, set its subtree S to be T and invoke **Insert_RT** to insert E into S. If resulting subtree S was split having a sibling S′, find a room in T to insert returned *tempentry* that points to S′, and adjust the MBR of S. When T was full, invoke **Node_Split**.
- **NLI3.** If selected C was split previously (its node-id is a nonzero positive value), invoke **Check_Contain** to check if new entry E is completely nested within C, if yes, set subtree S of C to be T and invoke **Insert_RT** to place E. When the resulting subtree S is split again, invoke **Contain_Adjust** to modify the family path.
- **NLI4.** If C was previously split but not entirely cover E, invoke **Choose_Entry** and **Check_Adjacency** repeatedly until there is an entry in the remaining entries of T that is optimal in coverage and adjacent to E, then set its subtree to be T and invoke **Insert_RT** for E. Otherwise, meaning non of remaining entries adjacent to E, create a new leaf node to place E, duplicate the MBR of E to that of the parent entry in T pointing to the E.

Table 2. (continued)

Algorithm Contain_Adjust

- **CA1.** If the subtree S of C has a normal overflow split (i.e. negative node-id is returned), create a new entry with node-id and timestamp copied from C since both S and sibling S′ are children entries of C; install the returned *tempentry* in T pointing to S′. If T was full, invoke Node_Split.
- **CA2.** If S has a spatial subdivision (i.e. a tuple-id is upgraded/returned), create a entry in T by appending upgraded tuple-id to existing node-id of C, and extending the timestamp interval. When T has room for this entry, insert it, otherwise, invoke Node_Split.
- **CA3.** Adjust the MBR of subtree S as one child entry is removed.

Algorithm Get_MBR

- **GM1.** Set the first non-empty entry to be initial value of x,y extremes.
- **GM2.** Compare x, y coordinates of each entry in a node with current extremes, and update the extremes when necessary.
- **GM3.** Return the final MBR in the form of [xmin, xmax, ymin, ymax].

Algorithm Choose_Entry

- **CE1.** Set new rectangle coordinates to be the initiate values.
- **CE2.** For each entry in the node, calculate the area and enlarged area by enclosing the new rectangle.
- **CE3.** Compare each enlarged area, choose the entry with the least area of enlargement, i.e. the difference between area and enlarged area is the minimum.
- **CE4.** Return the index of that entry.

Algorithm Node_Split

- **NS1.** For all M+1 entries (M entries for a full node, and new entry E), calculate the centroid of each rectangle, and distances of each pair of centroid, record the indices of two entries with the longest distance.
- **NS2.** Calculate angle of the longest distance to X axis.
- **NS3.** Choose splitting axis. If the angle is less than and equal to 45 degree, the splitting axis is Y, otherwise it is X axis.
- **NS4.** Distribute M+1 entries to two nodes. Compute the average on the splitting axis, the average is used as a threshold to divide entries into two nodes.

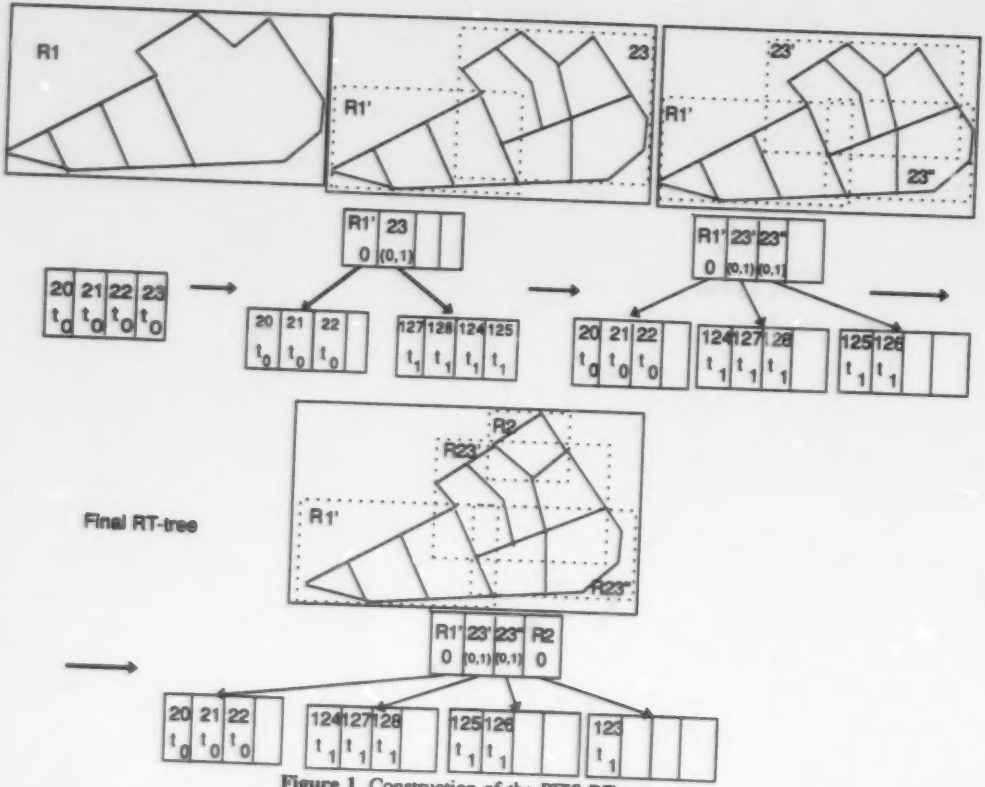

Figure 1. Construction of the PFIS RT-tree.

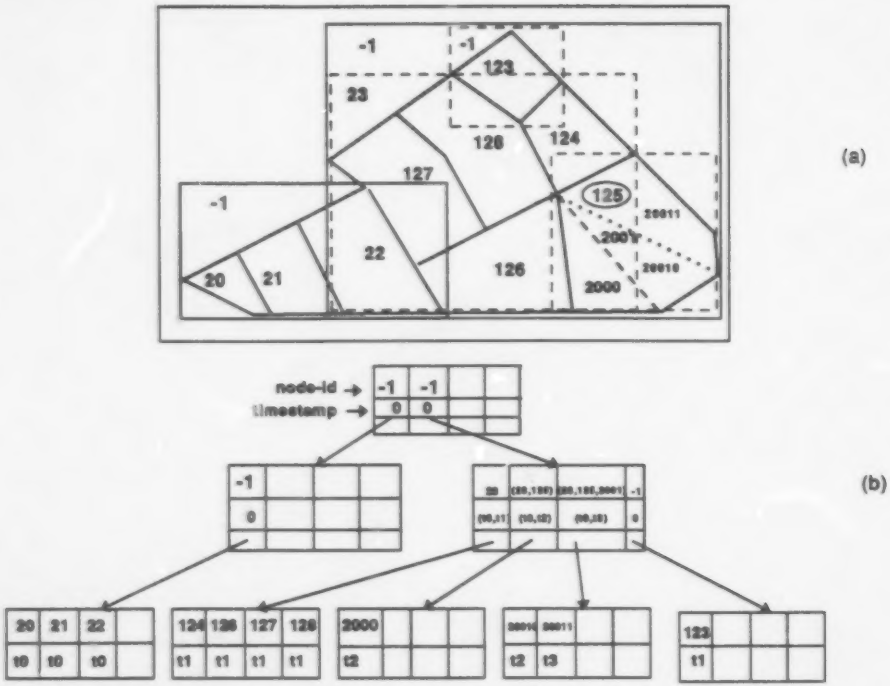

Figure 2. Multiple split on parcel 125 (a) and the RT-tree (b).

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PEN-BASED PORTABLE COMPUTER TECHNOLOGY FOR GIS FIELD ACTIVITIES - CURRENT USE AND OUTLOOK

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Abstract

The author addresses the problems involved in the capture and updating of graphic and non-graphic data in the field and the validation and synchronisation of geomatic themes, discussing the computerization of these important but often neglected functions. Following a research and development project in field data collection, the interesting prospects that have opened up for users include an easy-to-use tool for both consultation and direct updating of digitized maps. The tool is made available to field personnel on a portable computer having no keyboard. With an eye to the concerns of managers responsible for maintaining an up-to-date GIS, the author introduces some original and innovative approaches to the problem.

LA TECHNOLOGIE DES ORDINATEURS PORTATIFS A RECONNAISSANCE DE L'ECRITURE POUR LES ACTIVITES SUR LE TERRAIN RELATIVES AU SIRS - UTILISATION ET PROSPECTIVES

Résumé

L'auteur aborde la problématique de la saisie des données descriptives et graphiques sur le terrain ainsi que la validation et la synchronisation des thèmes géomatiques en élaborant sur l'informatisation de ce champ important mais trop souvent laissé pour compte. À la suite d'un projet de recherche et développement sur l'informatisation de la saisie, des perspectives intéressantes s'offrent à l'usager en fournissant un outil convivial de consultation et de mise à jour lui donnant accès sur le terrain à des cartes graphiques infomatisées via un ordinateur portatif sans clavier. L'auteur se penche donc sur les préoccupations des gestionnaires qui ont à cœur le maintien d'un SIRS à jour tout en introduisant des concepts et approches innovatrices à ce problème.

1. Introduction

As the importance of geographic information systems (GIS) and automated mapping grows rapidly in organizations that need to manage territorial assets efficiently, new concerns related to the updating of digitized graphic data are emerging.

At the same time as the computerization of office-based geomatic functions is taking users virtually to the space age, users have been discovering that the collection of update data in the field leaves them back in the stone age, or at least the paper era. (One exception is the capture of coordinates with total station and electronic notebook.)

When information maintenance requires field observations in which graphic information is viewed, created or added to existing digitized maps or plans, today's users must still handle paper versions of these plans, annotating them manually while noting non-graphic data on forms. The data, both graphic and descriptive, must then be re-entered for validation and processing by central databases.

To address these difficulties, research has been undertaken to computerize the capture of graphic and non-graphic data by means of the most recent user-friendly technologies.

The initial objective was to supply a need for an easy-to-use, portable computer-aided drawing (CAD) tool. This need was identified in a project carried out jointly by private enterprise and three municipal governments. The partners in the project were the Montreal Urban Community, the Québec City Urban Community, the City of Laval and Consortech Inc. The CAD tool was intended to computerize the sketching of buildings by residential property inspectors as part of the property assessment process (see Figure 1, Scale Drawing of Building With Outbuildings).

A solution incorporating the capture of both graphic and non-graphic data was developed in an evolutionary prototyping approach and field-tested by the three municipal administrations. Following significant enhancements to the graphics functions, they were tested by another Canadian province in a context of integrated inspection.

1. Objectives

The objectives of the original property inspection project were similar to the objectives of computerized field updating of cartographic and related non-graphic information:

- to eliminate office re-entry of data for processing by the central system;
- to allow the quality of captured data to be controlled at the source;

- to significantly reduce the handling of paper (plans, drawings, forms) and the number of intermediate personnel.

In sum, the aim of computerized field data capture and updating is improved productivity, with the ultimate goal of a paperless organization of work.

3. Requirements of Field Operations

In addition to portability, computerization must take into account the following characteristics of field operations:

- Most field personnel have very little familiarity with information systems or geomatic technologies. The tools must be very easy to learn and use.

- Access to graphic or cartographic data interacts with the parallel capture of non-graphic information. The field tool for capture and display must accordingly integrate graphic access functions with field processing of non-graphic data.

- The portable graphic system should support a procedure analogous to the paper-based procedure of annotating and correcting plans extracted and produced by the central system, while providing the benefits of direct electronic transfer of updated data to the central system.

- Data modified or created in the field must be synchronized with data maintained on the central system.

4. The Research and Development Project

The first step of the R&D project carried out by the private-sector partner was to identify the most appropriate technology for the requirements and objectives of the field application. The solution adopted was the very recent technology of pen-based portable computers. This solution provided the following benefits:

- portable equipment with a laptop-type screen of adequate size;

- operating system compatible with that of conventional PCs;

- ease of use provided by a combination of electronic pen and handwriting recognition facilities, eliminating the need for a keyboard.

The challenge was then to take this platform – easy to use but limited in its technical resources – and develop for it graphics editing functions, with their great demands on processing power, and an ability to store and manage non-graphic data and cartographic data, with their great demands on storage space. And response times, of course, had to be impeccable.

After demonstrating the operational feasibility of basic CAD-type graphic functions, the R&D project had to meet additional requirements for the more complex graphics functions required for the inherently more sophisticated process of cartographic updating.

Among these additional requirements were:

- connectivity with widely used graphics editors such as Microstation or AutoCad, to allow extraction and transfer of original digitized plans and the return of plans following corrections or annotations in the field;
- synchronization of geomatic themes or layers maintained on the central system with those modified in the field;
- multiple modes of manipulating graphic data;
- annotation of the existing plan (redlining);
- vector-mode modification;
- handling of polygons for calculation of perimeters and areas.

5. A Typical Computerized Field Updating Process

It is accordingly now possible to envisage a computerized process for field updates integrated with GIS or automated mapping solutions running on a central platform and linked to central data base for field-captured non-graphic data. The process would resemble the following:

On receiving an inspection request initiated by management requirements (e.g. land development, periodic inspections), the field inspection supervisor, using a workstation running the graphic system or the GIS, builds the routes of the inspection sites, consisting of extracts of digitized maps from the central system (see Figure 2, Digitized Map on Microstation).

These maps may be topographic, cadastral or infrastructural, depending on the nature of the field work involved. The supervisor can also preselect the layers required for the inspection or limit the available field functions to those authorized – e.g. direct entry of corrections, or redlining annotations only.

The extracts built in this way are transferred to the inspector's pentop computer. If computerized descriptive data is available, it is transferred to the portable computer as well.

In the field, the inspector brings to the screen the entry forms for descriptive data and uses the electronic pen to enter the required information interactively. Simple or sophisticated validations are executed instantaneously for improved data quality.

The inspector then calls up the plan of the area to be inspected (see Figure 3, Digitized Map on the Portable Tool) for modification or annotation. In an automated mapping context, the inspector can make the observed corrections on the appropriate layer or layers. In a GIS context with graphic elements linked to descriptive data, the inspector's capture of changes to existing graphic entities is obviously restricted in most cases to the annotating of changes to be made on the central GIS system that protects and manages the links.

On completion of the inspection, the cartographic and descriptive data is transferred to the central bases. Updated graphic data could directly replace the superseded version.

6. Benefits

This kind of approach for computerized data capture and updating provides obvious benefits in the form of productivity gains in a hitherto neglected aspect of geomatic operations. The approach reduces the cost of field data acquisition by:

- eliminating data re-entry and the intermediate handling of paper-based graphic and descriptive data, through direct or indirect computerized transfer;
- reducing the high costs of plotting on paper;
- improving the quality of the data captured through on-site verification and synchronization of graphic data and through direct validation of related descriptive data;
- reducing the time lags inherent in a manual process requiring actions by a number of different people.

7. Outlook

Although the technology for easy-to-use field updating has only recently become available, it is undergoing the same accelerated evolution as microcomputing in general. This evolution is towards platforms of greater power, lightness, storage capacity and handwriting recognition facilities.

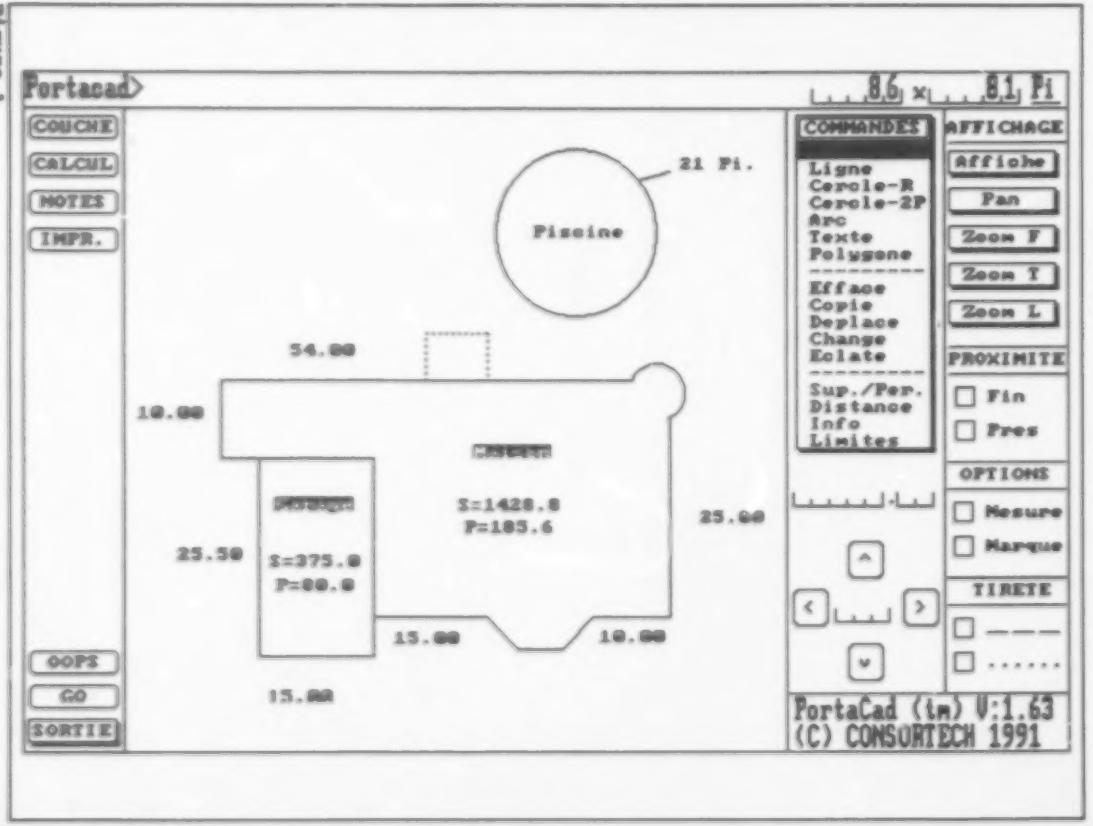
Advances in the technology makes available lightweight pen-based computers of great processing power (80386 processors) and high storage capacity (disks of 60, 120 or 200 MB and more). As a result there will no longer be constraints on the size of digitized map extracts that can be handled in the field.

In addition, the evolution of satellite positioning systems (GPS) already allows the direct transfer of coordinates to a field computer, which will be able to display them directly on a digitized map extract.

The resulting platforms and tools can be expected to benefit most field applications requiring interaction between access to digitized cartographic data and access to descriptive data:

- Public utilities will have access to map extracts to create or edit installation plans in the field and produce bills of materials for additions to facilities.
- Property inspectors will be able to integrate digitized building sketches, and even digitized photographs, with parcel maps.
- Municipal departments will be able to validate the interpretation of topographic maps directly in the field.

In summary, it is now possible to envisage the incorporation of computerized updating in the overall geomatic strategy, for maximum continuity in geomatic programs based on the availability of up-to-date data captured at less cost.


Portacad
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P=185.6
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P=80.0
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COMMANDES
Ligne
Cercle-R
Cercle-2P
Arc
Texte
Polygone
Efface
Copie
Deplace
Change
Eclate
Sup./Per.
Distance
Info
Limites
AFFICHAGE
Affiche
Pan
Zoom F
Zoom T
Zoom L
PROXIMITE
Fin
Pres
OPTIONS
Mesure
Marque
TIRETE
PortaCad (im) V:1.63
(C) CONSORTECH 1991

Figure 1

View Control
File Edit Element Settings View Palettes User
Lock-On
Current CT = user attached from disk
[10 ED TIP]
Main
View 1
BOULEVARD
Fence

Figure 2

Portacad>
91 x 85 M.
COUCHE
CALCUL
NOTES
IMPR.
BOULEVARD
COMMANDES
Ligne
Cercle-R
Cercle-2P
Arc
Texte
Polygone
Efface
Copie
Deplace
Change
Eclate
Sup./Per.
Distance
Info
Limites
AFFICHAGE
Affiche
Pan
Zoom F
Zoom I
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SCANNING ICE CHARTS ON AN APPLE MACINTOSH

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ABSTRACT

When faced with the task of digitizing existing maps and charts, many people are now turning to scanning as a potentially viable alternative to manual digitizing. In this paper we identify several key issues which are of concern when attempting to scan maps using a desktop scanning system: cost, efficiency, accuracy, scan resolution, storage requirements, and document size limitations. We illustrate our discussion by describing our development of a semi-automated scanning technique for the digitizing of composite ice charts produced by the Ice Centre at Environment Canada. We explain the design and operation of SICAR - the "Sea Ice Chart Archival System" for the Macintosh. This program significantly reduces the time required to digitize a map (over conventional digitizing) and increases the accuracy of the resulting digital chart. The data set which is created has a simplified structure for easy access by other software tools.

LECTURE OPTIQUE DES CARTES DE GLACES SUR MACINTOSH APPLE

RÉSUMÉ

Au moment de numériser des cartes existantes, bien des gens recourent maintenant au lecteur optique comme remplacement potentiellement viable de la numérisation manuelle. Nous cernons ici plusieurs domaines clés à prendre en considération quand on tente de procéder au balayage de cartes à l'aide d'un système de bureau. Nous illustrons la discussion en décrivant comment nous avons élaboré une technique semi-automatique de lecture optique pour la numérisation des cartes composites des glaces produites par le Centre des glaces d'Environnement Canada. Nous donnons des détails sur la conception et le fonctionnement du SICAR (Sea Ice Chart Archiving System, ou système d'archivage des cartes des glaces de mer) sur Macintosh. Ce programme permet de réduire considérablement le temps nécessaire à la numérisation d'une carte (par rapport à la méthode classique) et augmente la précision de la carte numérique résultante. L'ensemble de données ainsi créé présente une structure simplifiée le rendant accessible à d'autres outils logiciels.

1. INTRODUCTION

The Ice Climatology Section within Environment Canada (ICEC) has been compiling weekly "composite ice charts" depicting ice conditions (age, thickness, type) in Canada's coastal waters for the past thirty years (Figure 1). These maps are derived from daily observations acquired by various combinations of remote sensing using airborne synthetic aperture radar, visible and infrared satellite imagery, and ship navigation reports. In the past, the maps have been manually drafted but a new, technologically advanced, system has now been installed which produces the ice charts digitally [Falkingham *et al.*, 1990]. ICEC wishes to facilitate the integration of the existing hard copy maps with the new digital products in a compatible data base.

One of the primary research thrusts within the Earth Observations Laboratory (EOL) at the University of Waterloo is the study of cryospheric processes within a Global Change context. It is apparent that sea ice is sensitive to climate and the greatest changes due to greenhouse effects are predicted to be in the Arctic. Yet the coupled interactions between ocean, atmosphere, and sea ice are poorly understood and only crudely modeled. Thus the need for fast and easy access to historical ice information in digital form has never been greater.

Thus it was for different, but parallel, needs within ICEC and EOL that the requirements for digital conversion of the historical ice chart archives were developed. Manual digitizing of the ice charts had been attempted by ICEC in the past but the results were not satisfactory. In 1990, ICEC and EOL joined forces to develop a semi-automated scan-digitizing program. Our prime objectives were to be able to digitize the ice charts faster, more accurately, and less expensively by scanning than through manual digitization.

In this paper, we explain the design and operation of SICAR - the Sea Ice Chart Archival System for the Apple Macintosh microcomputer. We begin our discussion by providing an overview of the scanning process. We then describe the characteristics of composite ice charts which make them difficult to work with in an automated environment and describe how we have developed SICAR to process them. Through our attempts at extracting information from scanned maps, we were able gain first hand experience in many of the aspects of cartographic scanning in general. We summarize some of the lessons we learned in the fifth section of this paper.

2. SCANNING

Scanning of maps is becoming an increasingly popular alternative to manual digitizing because of its increased throughput potential. The potential of scan digitizing lies in its perceived ability to *totally* automate the digitizing process: to simply feed a map into one end and get a topologically complete spatial database at the other end. While scan digitizing can be five to ten times faster than traditional manual digitizing, considerable operator intervention is still required during the information extraction process [Blakeman, 1987; Chrisman, 1987; Shea, 1987; Carstensen and Campbell, 1991].

There are two basic steps in the scan-digitizing process: scanning and feature extraction. Scanning is the process by which a scanner records an "image" of the original document and saves it on the computer's disk. Although the scanned image *contains* the information we are interested in, the data are still not in a usable form. For example, an image of a topographic map does not yield a digital elevation model - this must be extracted.

The second stage of the scanning process, therefore, is feature extraction. Using specialized software, map features are identified in the scanned image and saved in a compatible form for inclusion in further spatial data analysis. Since each map type is unique in many ways, it is difficult to develop a generic feature extraction program. Consider, for example, how information from a typical topographic map could be included within a Geographic Information System (GIS).

Most GIS require that each specific data type (e.g., topography, hydrography, road network) be stored in a separate layer or coverage. All of these features are co-occurrent on the map sheet, however. After scanning, it is up to the feature extraction software to correctly separate them on the scanned map image. Further, some topographic mapping features (e.g., swamps) may not have the well-defined boundaries required of many GIS. The limits to these areas must somehow be determined as polygons during the feature extraction process. In comparison, during traditional manual digitizing the operator selectively digitizes only the features of interest and assigns identification "tags" to each item, hence the feature extraction stage is an implicit part of the procedure.

Current scanning software designers are attempting to increase the applicability of their programs by including a wider range of cartographic symbol interpretation capabilities. For example, some systems are now capable of extracting information from scanned maps by grouping features according to line thickness [Waters *et al.*, 1989; Galdins, 1990], object size [Sidebottom *et al.*, 1990], and feature colour [Waters *et al.*, 1989; Jolicoeur, 1990]. Sidebottom *et al.* [1990] report some success in automatic numeral identification of contour labels. In a novel approach, Eveleigh and Potter [1989] have exploited some of the techniques used in multispectral image processing to group cartographic features.

To facilitate map symbol recognition, many authors recommend that there be some type of pre-processing applied to the map before the information extraction step. Gap and speckle filtering and line thinning in the scanned image are two of the more common processes [Greenlee, 1987; Shea, 1987; Galdins, 1990; Sidebottom *et al.*, 1990; Carstensen and Campbell, 1991]. Other studies recommend completely re-drafting the map *before* it is scanned [Peuquet and Boyle, 1984; Aronoff, 1989].

Each of the above examples inherently show that the recognition of map symbols and features remains one of the most difficult parts of the feature extraction process. Thus Peuquet and Boyle [1984] conclude, "the optimal input document is one which contains only one feature type drawn using a single, uniform line weight and which is as error-free as possible."

Most scanning software systems are designed around a specific map type; they are not well suited to different kinds of data. Unfortunately, very few people who want to exploit some of the advantages of scan digitizing have maps which are similar to the maps used by existing programs or are as pristine as Peuquet and Boyle would have them. To avoid the expense of developing new scan conversion software, these users frequently revert back to manual digitizing. When we were faced with the problem of digitizing an *atypical* map sheet, however, we decided to attempt the scanning approach. A review of existing scanning software packages did not provide us with a suitable "off-the-shelf" program, so one was developed specifically for our project: the Sea Ice Chart Archival System (SICAR).

3. Composite Ice Charts

In a composite ice chart (Figure 1) areas of similar ice concentrations are outlined by a single polygon. Each polygon is given several attributes identifying the sub-classes of ice types and concentrations which compose it. The methods of tagging the attributes with a polygon have varied over time, but now follow an international "egg symbol" convention.

While these ice charts are quite readable from a human perspective, they are challenging for automatic feature extraction software. The polygon outlines, egg symbols, latitude and longitude graticule, and coastlines are all drawn using a similar line weight and colour. This precludes the application of standard feature recognition techniques using colour and line thickness. To further confound the issue, one class of polygon, for shore-fast ice, uses solid shading rather than the usual unfilled polygon.

4. SICAR - The Sea Ice Chart Archival System

In order to meet the system objectives of minimizing costs and maximizing ease of use, we built our system on an Apple Macintosh microcomputer. We have found the Macintosh user interface to be very intuitive and its windowing capabilities are well suited to this application. In the following sections we describe the functionality of SICAR from a user's perspective.

4.1 Initialization

The primary input to SICAR is a scanned ice chart. The actual scanning process (capturing an "image" of the paper map) involves positioning the map in a scanner and invoking a simple program to drive the device and save the image on disk. Since several such programs are available from scanner manufacturers, this step of the process in not part of the SICAR program. Instead, our program can read these data from a file in a standard microcomputer image file format (1-bit TIFF) which is a common output option from scanning programs. Upon initialization, then, SICAR requests the user to specify an image file for manipulation.

4.2 Polygon Identification

The goal of the feature extraction process is to obtain a definitive outline of each ice polygon which we can use to answer the question, "At any given point, what were the ice conditions found on the map?" Unfortunately, each polygon is frequently dissected into smaller segments by the projection graticule and egg symbols (see the inset in Figure 1). This means that the user must "build" a complete polygon definition from a collection of individual segments. Thus, the potential confusion of line features on the ice charts had a major influence on our selection of a method for polygon feature extraction.

Our solution to this problem was to implement a *raster fill* mode of polygon identification. The rationale behind this procedure is simple: If we can fill an entire polygon with the same shading pattern, then the outline of that area can be obtained by tracing around the shaded region. In practice, the user selects the interiors of different sub-polygons (by "clicking" in them with the mouse) while the system fills in these segments with a solid shade (Figure 2). This is repeated until an entire polygon is filled, at which point the polygon's definitive outline is assembled from each of the component segments. The filling algorithm can accommodate "white" regions defined by a black boundary, or "black" regions surrounded by a white boundary (as in shore-fast ice).

The user signals the program that the entire polygon has been shaded by holding down the *<shift>* key while clicking in the interior of the region - a "shift-click". The shift-click location is checked for inclusion to be sure it lies within the shaded region. This point is saved along with the polygon boundary to be used as an interior label point during subsequent data processing. Starting at the top-left corner of the selected region, a background process "steps" around the polygon one pixel at a time to extract a linked list of boundary coordinates. After the trace is complete, an attribute window appears showing the extracted boundary (Figure 3).

4.3 Attribute Entry

There are two methods which have been used in the past to label the attributes for each polygon. On early maps (until 1981), a ratio-style of labelling was used. Various attributes were listed above and below a solid line, depending on the ice concentrations and ages represented by the polygon. Entries in a ratio-style attribute list were position specific. In the early 1980's ICEC joined with the World Meteorological Organization in developing an international ice polygon symbology. The newer symbol contains the ice type attribution in a vertical oval, hence it is most frequently referred to as an egg-style label.

During the development of SICAR, we recognized that the manual entry of the polygon attribute lists would be one of the most time-consuming and (hence) error-prone tasks which the user would have to do. We designed the attribute entry windows to mimic the form of the labels on the map to speed up and increase the accuracy of the attribute transcription process (Figure 3).

As the user types the ice attributes, several consistency checks are made at two levels. First, each value which is entered is verified against a list of permissible entries for that position within the attribute list. These are the primary checks. Since many of the values are related to each other, secondary checks are made to verify these relationships after each group of attributes have been entered. For example, in the egg-style lists, the sum of the partial ice concentrations listed in the second row must equal the total concentration listed in the top row. Any failures in the consistency checks are reported to the user. These will most likely be due to a transcription error (primary check failure), at which point the user can go back and correct their mistake. It is possible, however, that the inconsistency may occur in the original map label (secondary check failure). In this case, the user may elect to correct the problem or ignore the consistency check. All primary errors must be resolved; secondary checks can be overridden.

Additional features of the attribute entry dialog include: using the preceding polygon's values as initial defaults (since adjacent polygons tend to have similar conditions), automatic field filling to avoid null entries in the database, single key-stroke data entry to speed up typing of double character fields (e.g., *<shift> 1* is typed to enter the value "10"; *<shift> 9* is typed to enter the value "9+"), a quick-entry check box to indicate a region of shore-fast ice, and the facility to accommodate multiple attribute lists for a single polygon.

4.4 Georeferencing

After all of the polygons have been entered, the data are exported to disk for storage. The first step of this process is the translation of the polygon outlines from the screen coordinate system of the computer to latitude and longitude. There are five base maps which have been used for the compilation of the ice charts (Figure 4). These are drawn at a scale of 1:4,000,000 on a Lambert Conic Conformal projection using the standard parallels of 49° and 77° north. This information is used during the export function to translate from screen to projection coordinates.

To facilitate this translation, a common point in both coordinate systems must be identified. The projection coordinates for each of the base map's bottom left corners are stored within SICAR, the user is prompted to identify that spot on the scanned image. To accommodate maps which have not been scanned at a perfectly horizontal orientation, an affine transformation is applied to the screen coordinates to rotate them (if necessary) before their conversion to latitude and longitude. This requires that a horizontal line be located in the scanned image. Since the user has already identified one point along the map's bottom border, they are next requested to select the map's bottom right corner on the screen.

The actual conversion to latitude and longitude takes place as the polygon outlines are written to disk. The projection transformation is applied following the method described in Nagy [1990] using the GRS 1980 spheroid. The coordinates are recorded in decimal degrees, rounded to the nearest three minute interval (i.e., 1/20TH of a degree). This approximates the precision of the original linework on the maps at southern latitudes and exceeds that accuracy in the polar areas.

4.5 Exporting Data

One of our design criteria for SICAR was the provision of efficient gateways for data exchange with other spatial information systems. Therefore, the primary output from the scanning process is a readable text file (ASCII) with the complete definition for each polygon contained on one line

(Figure 5). In addition to the data which are entered during polygon identification and attribute entry, the polygon's size (number of outline coordinates) and its bounding rectangle (minimum and maximum coordinates) are also recorded. The bounding rectangle can be used during subsequent data retrievals to identify candidate polygons which may contain a specific point.

4.6 Bitmap Editing

On occasion, it may be desirable to modify the scanned image to fill in gaps in polygon outlines created during scanning, or to create "holes" in some of the scanned linework which may be causing a problem with the tracing program. We have provided an interactive bitmap editing function to assist the user in these regards.

With the scanned image window in the foreground, the bitmap editor is invoked by engaging the *<caps lock>* key on the keyboard. The display cursor changes from its default "cross-hairs" setting and into a pencil (Figure 6). When the mouse button is pressed, any image pixels under the cursor are inverted. That is, any white pixels become black (so that gaps can be closed) or any black pixels become white (to open up holes as required). Disengaging the *<caps lock>* key returns the cursor to its normal operation. All modifications to the scanned image are permanently recorded.

4.7 Potential Enhancements

In the preceding discussion, we have described the operation of SICAR as it currently exists. After having used the program for some time, there are several areas of further development which may enhance its operation.

4.7.1 Polygon Identification by Line Following

SICAR currently uses a *raster fill* method to identify ice polygons; an alternative approach could be through *line following*. The user would initiate the line following method by pointing at one section of the polygon boundary to be traced. The system would then follow that boundary as far as it can - until a point of indecision is reached (multiple crossing lines or a gap, for example). The operator would then point to the next section of the outline and the system would connect it to the first. The process would continue until the entire polygon is traversed.

Although a preliminary evaluation of the two approaches indicated that the raster fill technique had the highest potential to be the most efficient in terms of both elapsed time and operator interaction/fatigue (hence it was selected for the initial implementation), a definitive conclusion cannot be made until the line following technique is implemented. It may be discovered that one approach excels for different map types or is more usable by different operators, so both could be implemented in an ideal environment.

4.7.2 Grid Removal

Perhaps the most confounding aspect of the scanned charts is the inability to separate the projection graticule from the ice polygons. It is possible to recognize the grid on a scanned map through comparison with a previously processed base map or by predicting its location at known intervals and searching for regular (i.e., straight or gently curved) lines. Subtracting the grid from a scanned map may not improve the program's operation, however, since this would introduce gaps into the polygon outlines. Some of these gaps could become significant where an outline and grid line are coincident for some distance. Further testing is required to determine the effects of grid removal.

4.7.3 Map Preprocessing

Some authors suggest that complex maps be re-drafted into theme separates to facilitate automated feature extraction [Peuquet and Boyle, 1984; Aronoff, 1989]. Re-drafting also allows for any changes or updates to be made to the map's content. Both of these reasons were rejected in this study because: (i) the maps reflect historical "snapshots" of ice conditions, hence they do not need to be updated; and (ii) re-drafting the maps to simply show the ice polygon boundaries would require at least as much extra time and cost as manual digitizing.

Other studies suggest that the application of noise and speckle removal, and line skeletonization routines improve the automatic line tracing abilities of the particular system involved [Greenlee, 1987; Shea, 1987; Galdins, 1990; Sidebottom *et al.*, 1990]. Initial testing in these areas has shown positive results.

4.7.4 Symbol Recognition

Most scan digitizing systems, including SICAR, concentrate on extracting the spatial information from a map, leaving the attributes to be entered manually at the keyboard. With the increased speed at which a user can digitize lines in these programs, the slowest part of the process quite often becomes this manual interaction. Optical character recognition programs are available, but these are not well suited to the identification of characters, such as those found on the ice charts, which are not typewritten in a standard font or are not at a horizontal orientation. Some progress in map symbol identification is reported by Sidebottom *et al.* [1990] but more research effort is required to make this a reliable alternative .

5. LESSONS LEARNED

Throughout the development of SICAR, we were faced with design choices which influenced the ultimate operation of the program. Many of these issues are a direct result of the infancy of cartographic scanning technology and are of concern to anyone contemplating the adoption of desktop scanning. Specifically, this discussion is targeted towards users of mid-range desktop scanners with limited resources.

Lesson 1: Scanning Can be Cost Effective

Scanning may be more expensive than manual digitizing because more expensive equipment must be purchased and maintained and more sophisticated software must be acquired [Aronoff, 1989]. Digitizing tables represent a mature technology without many new innovations or price fluctuations. The capabilities of desktop flatbed scanners, on the other hand, are increasing while their prices are decreasing [Carstensen and Campbell, 1991]. This is making the hardware price differential between the two technologies less critical.

Another advantage of manual digitizing is that inexpensive data capture programs are readily available, whereas scanning often requires the acquisition or development of sophisticated, therefore expensive, software.

For small digitizing projects with only a few maps to be processed, manual digitizing is still the best solution. The higher startup costs associated with scanning become less significant, however, if distributed over the course of a large digitizing project, such as SICAR. Therefore, scanning becomes increasingly cost-effective as more maps are digitized.

Lesson 2: Scan-Digitizing is Faster than Manual Digitizing

The time required to actually scan a map (i.e., the data capture stage) is brief - about the same as the amount of time required to securely affix a map to a digitizing table. The feature extraction stage can be considerably faster in scanning, however, principally because the data are then already in digital form. This means that the power of a computer can be used to speed up some typically slow manual processes. When digitizing a curvy road, for example, some feature extraction programs simply require that the operator move the cursor to some point on that road (on a displayed map image) and the software will automatically trace its form. In the manual method, the user must follow the road by hand.

A considerable amount of manual editing is still required during feature extraction of scanned maps, however. For example, when tracing a road in a scanned image the program may detect a crossroad. Some sophisticated software may be equipped with a decision rule which automatically elects to continue the road trace after the intersection in the same general direction which the feature was travelling previously. This is probably a valid decision in most cases, but it might not always hold. How the software reacts to road junctions in the form of a "Y" may also lead to inconsistent results.

Feature extraction programs may stop at points of indecision and request user direction or the user may have to edit incorrect choices afterward. A major difficulty with the second approach is that all errors may not be apparent during the editing stage, especially if they do not compromise the consistency of the map.

When compared to manual digitizing, the entire scan-digitizing process has been reported to be as much ten times more efficient [Blakeman, 1987; Chrisman, 1987; Shea, 1987]. This is dependent on the type of map being processed and the robustness of the feature extraction software. In our experience with SICAR, we have realized a more modest two- to five-fold throughput improvement. Even these gains are significant, however.

Lesson 3: Scanning is Accurate

The accuracy of the conversion process is also an important consideration when evaluating the scanning approach. For spatial data, Shea [1987] reports that the accuracy of line following is much greater when automated because this "generally removes the user from the conversion loop, thereby eliminating human frailties in the digitization process (such as physiological and psychological deficiencies)." That is, a computer can follow a line more consistently than a human digitizer.

Carstensen and Campbell [1991] evaluated the planimetric accuracy of a desktop scanner by comparing the distances between several precisely located points on a test document with their spacings in scanned images of that document. They concluded that the planimetric accuracy of the source document was not compromised and error levels were not affected by the scanning density used nor by the distance between the tested points.

On the other side of the accuracy issue, however, White and Owens [1990] found that attribute errors in the original map sheet were easily identified, and corrected, during manual digitizing, but were frequently hidden in the scanning approach.

In our examination of check plots of the exported polygon boundaries from SICAR we have not found any significant deviations from the original chart document. We conclude, therefore, that spatial accuracy is maintained. Further, we have found (contrary to White and Owens [1990]) that SICAR has enabled us to identify attribution errors on the original charts and correct them before

entry into the digital archive. These errors are detected by the consistency checks made during the attribute transcription process.

Lesson 4: Scan Resolutions Should be Judiciously Selected

Closely related to accuracy is the scanning density or resolution used. In general, an increase in the resolution of the scan will lead to a more accurate rendering of the source document. A two-fold increase in resolution produces a file which is four times larger (Table 1), however, so there must be some practical limit to the scan density used. On the other hand, setting the scan resolution too low can result in a loss of detail and compromise feature integrity. Most flatbed scanners are capable of capturing an image of the map document at a variety of resolutions, ranging from 75 dpi (dots per inch[1]) to 300 dpi. Some drum scanners have resolutions of 1000 dpi or even 2000 dpi. The optimum scan resolution should be ultimately determined by the scale and accuracy of the source map as well as the intended use of the data.

Peuquet and Boyle [1984] suggest that most lines on a map which have been drawn with standard cartographic precision (e.g., using coordinate geometry and scribing) do not warrant a scan density of more than 250 dpi. While the ice charts which we have been using in this project are accurate for their intended purpose, they have not been drafted with such precision. These maps are compiled by visually transferring ice information from remotely sensed images to a base map on paper stock using technical pens. At the original map scale of 1:4,000,000, a 0.04 inch displacement of a polygon boundary - about one line-width - on the map corresponds to a 2.5 mile shift on the ground. As illustrated in Table 2, even the lowest scan density achieves a much better ground resolution than this. We specify the optimum scan resolution to be at the minimum density (for the smallest files) which will provide an acceptable image for the feature extraction algorithms. In our case, for SICAR, this is near 100 dpi.

There is a tendency to "overscan" maps where a higher scan resolution is used in order to obtain a good pictorial presentation of the original document. This may be an appropriate goal when scanning figures for desktop publishing, but when processing cartographic images the scan density should be set according to the map accuracy.

Lesson 5: Scanned Maps Require Lots of Storage

In addition to the scan resolution other factors which significantly affect the size of the resulting image are the size of the original document and the scanning mode (Table 1). Problems may arise during the scanning, feature extraction, and file storage stages if the image sizes exceed the limitations of the system hardware and software.

The scanning mode selected for a map - binary, grey-scale or colour - depends on the type of map that is being scanned, the capabilities of the scanner and feature extraction software, and how the final digital map will be used. The simplest type of map contains only black lines of equal weight and no shading or colour patterns. Ice charts are examples of this map type. The system need only be able to determine the presence or absence of a line in this case, so binary mode can be used. This type of *bitmap* may be appropriate for imaging contours from a topographic map (if they can be uniquely distinguished from the other map features), however, thematic maps containing features which are differentiated through the use of colour or tone must be scanned in the appropriate grey-scale or colour mode. Since scanned image size is dramatically affected by the scanning mode, binary mode should be used whenever possible.

[1]Imperial units of measure are used in this text in accordance with standard North American scanning terminology.

Lesson 6: Most Maps are Too Big for Desktop Scanners

The difficulty encountered most often with desktop scanners are their limitations in size. The largest ones are now only capable of handling documents measuring up to 14" x 17" while many map sheets are over twice these dimensions. Users of desktop scanners are left with the choice of either reducing the size of the original document (mechanically or photographically) or scanning the map in sections and "mosaicking" them back together with software. In the first case, there may be some loss of detail in the map which may be compensated for (in some simple cases) by increasing the scan resolution, if possible. Care must also be taken not to introduce any geometric distortions during the reduction process. Image mosaicking can be effective but it requires that the system have the necessary software and large memory resources, which is often its limiting factor. In either case, the overall efficiency of the scanning procedure is reduced because this extra step is required.

6. Summary and Conclusions

Digitizing existing maps for use in computer-assisted cartography or GIS remains one of the major obstacles to effective use of our existing map base. Scan digitizing has a great potential to revolutionize the cartographic digitization process, but only limited progress has been demonstrated to date. This slow advance is largely the result of the fact that most of our map documents contain multiply-overwritten features and labels which confound any automated approach to information extraction.

The first consideration which should be made when evaluating scanning technology for a given application is the complexity of the maps which are to be digitized. If the desired features are unambiguously portrayed - that is, unique with respect to style, tone or colour, and not in conflict with any other map symbol - then scan digitizing may be possible. Peuquet and Boyle [1984] conclude, "the optimal input document is one which contains only one feature type drawn using a single, uniform line weight and which is as error-free as possible." Unfortunately, the composite sea ice charts which we wished to scan failed to meet this simplistic description.

The second step in a scanning evaluation is to locate any available feature extraction programs which match the target map type. If the search is successful, bear in mind that no program is totally automated - a considerable amount of operator editing will still be required to clean up the digital map information. Users who cannot locate an available program frequently revert back to manual digitizing to avoid the expense of developing new conversion software. We elected to develop a specialized software package - SICAR - for use with the ice charts. Although the development of this program was considerably more costly than the acquisition of an "off-the-shelf" manual digitizing package, it was our view that these expenses would be recovered over the duration of the digitizing project since there were almost 5,000 maps to be processed.

Through our attempts at extracting information from multi-featured monochromatic maps, we were able gain first hand experience in many of the aspects of cartographic scanning in general. We have documented some of these issues with the hope that our experiences will assist others in tackling similar problems. In many situations, however, the choices between several design criteria may already be pre-determined by the characteristics of the destination GIS for the scanned map.

We still have a long way to go before fully automated scanning systems become available. In the interim, we will have to continue to rely on the human capabilities of spatial referencing in conjunction with the computer's ability to repeatedly perform routine operations to extract information from scanned maps.

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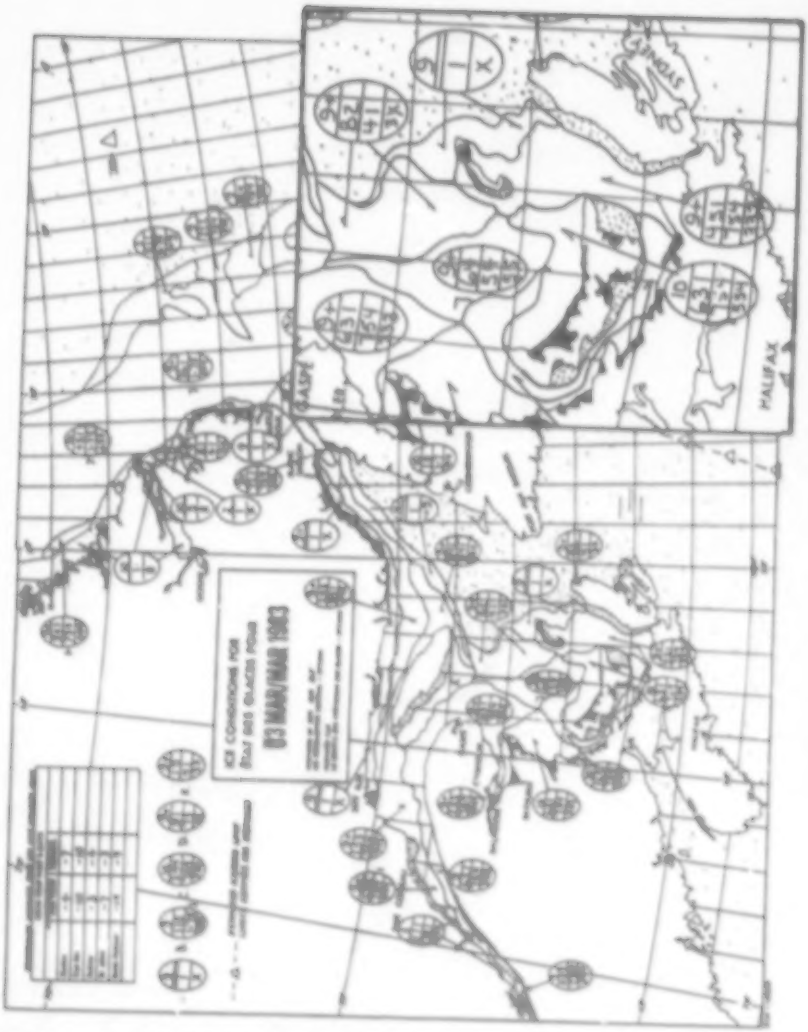

Figure 1: Example of a Composite Ice Chart.
This map has been reduced from its original size of 24" x 36" cm. The inset shows some of the map detail at the original scale of 1:4,000,000.

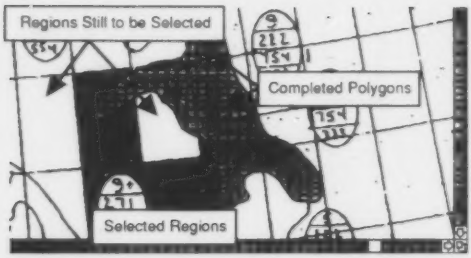

Figure 2: Selecting Sub-Polygon Regions.
The current set of regions are shaded dark; the lighter shade represents completed polygons.

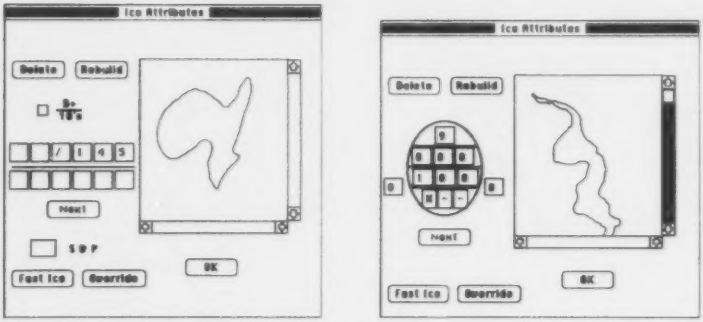

Figure 3: Ratio-Style and Egg-Style Attribute Entry Windows.

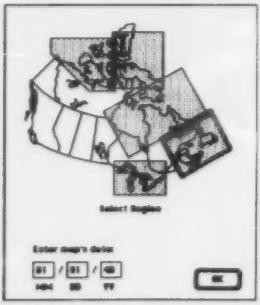

Figure 4: Ice Chart Base Map Locations.

Figure 6: Scanned Image Editing with the Pencil Tool.

Label Point	Attribute Data	Min/Max Lat/Lon	#	Boundary Coordinates
50.05,66.40,	10,10,0,0,0,0,0,8,-,-,0,0,0,	50.20,66.80,49.95,66.25,	34,	50.25,66.50,...
47.45,61.60,	10,10,0,0,0,0,0,8,-,-,0,0,0,	47.55,61.70,47.40,61.45,	16,	47.55,61.55,...
45.65,62.65,	10,10,0,0,0,0,0,8,-,-,0,0,0,	45.75,62.80,45.55,62.35,	26,	45.75,62.75,...
45.85,63.70,	10,10,0,0,0,0,0,8,-,-,0,0,0,	46.05,64.10,45.65,63.05,	58,	46.05,64.05,...
46.10,62.95,	10,10,0,0,0,0,0,8,-,-,0,0,0,	46.30,63.30,45.95,62.85,	44,	46.30,63.00,...
46.40,63.20,	10,10,0,0,0,0,0,8,-,-,0,0,0,	46.80,64.10,46.35,62.60,	92,	46.80,64.05,...
46.15,62.50,	10,10,0,0,0,0,0,8,-,-,0,0,0,	46.35,62.60,45.95,62.05,	38,	46.35,62.10,...
46.35,61.80,	9+,4,5,1,7,5,4,3,3,3,0,0,0,	46.95,62.50,45.55,61.10,	126,	46.95,62.15,...
47.10,61.75,	9+,4,5,1,7,5,4,3,3,3,0,0,0,	47.50,62.35,46.95,61.30,	89,	47.50,62.00,...
46.60,62.45,	10,6,3,1,7,5,4,5,5,4,0,0,0,	47.05,64.00,46.40,62.00,	127,	47.05,62.40,...
47.30,62.85,	9+,6,4,0,5,4,0,5,5,0,7,0,0,	48.60,63.80,46.70,62.30,	144,	48.60,63.15,...
47.70,61.50,	9,9,0,0,1,0,0,X,0,0,0,0,0,	48.30,62.30,46.70,60.85,	148,	48.30,62.30,...
47.75,62.35,	9+,8,2,0,4,1,0,3,X,0,0,0,0,	48.70,63.05,47.20,61.65,	118,	48.70,62.15,...
45.80,62.95,	10,1,6,3,7,5,4,4,5,4,0,0,0,	46.30,64.00,45.65,62.15,	100,	46.30,64.00,...
46.85,64.30,	10,1,6,3,7,5,4,4,5,4,0,0,0,	47.15,64.65,46.25,63.90,	74,	47.15,64.10,...
47.15,63.55,	10,1,6,3,7,5,4,4,5,4,0,0,0,	47.40,64.00,46.95,63.35,	44,	47.40,63.70,...
46.85,63.25,	10,1,6,3,7,5,4,4,5,4,0,0,0,	46.95,63.55,46.75,62.95,	31,	46.95,63.55,...
46.00,63.65,	10,6,3,1,7,5,4,3,3,3,0,0,0,	46.10,63.95,45.85,63.45,	47,	46.10,63.75,...
47.45,64.50,	10,6,3,1,7,5,4,3,3,3,0,0,0,	48.00,65.15,46.15,63.65,	175,	48.05,64.65,...

Figure 5: Example of an Export File From an Egg-Style Map.

Table 1: Storage Requirements for Scanned Images

Document Size	Scan Resolution	Image Size	Scanning Mode[1]	Storage Required
8.5" x 11"	100 dpi	850 x 1100	binary	0.1 Mb
8.5" x 11"	200 dpi	1700 x 2200	binary	0.4 Mb
8.5" x 11"	300 dpi	2550 x 3300	binary	1.0 Mb
8.5" x 11"	100 dpi	850 x 1100	grey scale/colour	0.9 Mb
8.5" x 11"	200 dpi	1700 x 2200	grey scale/colour	3.6 Mb
8.5" x 11"	300 dpi	2550 x 3300	grey scale/colour	8.0 Mb
24" x 36"	100 dpi	2400 x 3600	binary	1.0 Mb
24" x 36"	200 dpi	4800 x 7200	binary	4.1 Mb
24" x 36"	300 dpi	7200 x 10800	binary	9.3 Mb
24" x 36"	100 dpi	2400 x 3600	grey scale/colour	8.2 Mb
24" x 36"	200 dpi	4800 x 7200	grey scale/colour	33 Mb
24" x 36"	300 dpi	7200 x 10800	grey scale/colour	74 Mb

[1] Scanning Mode: binary - 1 bit/pixel; grey-scale/colour - 8 bits/pixel

Table 2: The Effect of Scan Density on Ground Resolution and File Size for Composite Ice Charts

Scan Density (dpi)	Ground Resolution (mi)[1]	File Size (Mbytes)[2]
75	0.84	0.6
100	0.63	1.0
150	0.42	2.3
200	0.32	4.1
300	0.21	9.3

[1] map scale is 1:4,000,000
[2] using 1 bit/pixel for a sample map measuring 24" x 36"

GIS in Environmental Assessment: A Linear Utility Case Study

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ABSTRACT

Environmental assessment studies involve the analysis of a considerable volume and variety of environmental information. Ecological Services for Planning Ltd. used GIS to identify and evaluate alternative transmission routes from the Ontario-Manitoba border to Nipigon, Ontario for Ontario Hydro.

In the route identification process, GIS was used to digitize maps of environmental indicators, overlay the indicators using a classification algorithm model, and plot maps of the overlay results. The output was used to identify alternative routes and sites. For route evaluation, the routes were digitized as discrete segments and the segments were buffered to create corridors. The segment corridors were then overlaid onto the environmental data to produce reports indicating the area of constraint crossed by each segment. These reports were combined in a spreadsheet which was used for a pair-wise evaluation of the segments in order to select the preferred route.

GIS increased our ability to manage the large amount of environmental data involved in this routing project. Through the analysis of the pattern of environmental constraints, it assisted the study team in the generation of corridors for the routes, and in the production of area data for the evaluation of alternative routes.

Les SIG Dans Le Processus D'Évaluation Environnementale: Étude De Cas D'un Tracé Pour Lignes De Transmission Hydroélectrique

Les évaluations environnementales impliquent l'analyse d'un volume et d'une variété considérable d'information environnementale. Ecological Services for Planning Ltd. s'est servi d'un SIG afin d'identifier et d'évaluer un choix de tracés de lignes hydroéléctriques pour Ontario Hydro s'étendant entre la frontière Québec-Manitoba et Nipigon, Ontario.

Un SIG a été utilisé dans le processus d'identificatien des tracés afin de numéraliser les cartes d'indicateurs environnementaux, d'intéger les indicateurs en utilisant un modèle de classification algorithmique et de produire des cartes découlant de l'intégration des differents niveaux de données. Ces cartes ont servi a identifier les tracés et les sites alternatifs. Lors de l'évaluation des tracés, ceux-ci furent numéralisés en tant que segments distincts et furent élargis en créant des corridors. Les segments corridors ont ensuite été integrés aux données environnementales afin de produire des rapports indiquant les aires de contraintes traversées par chaque segment. Ces rapports on été combinés dans un tableau qui a servi a évaluer les segments dans le but de sélectioner le tracé ayant le moin de contraintes environnementales.

Le SIG nous a permi de mieux gérer la grande quantité de données environnementales impliquées dans ce projet. Par l'analyse spatial des contraintes environnementales, le SIG a assisté l'équipe d'étude dans la création de corridors pour les tracés et dans la production de données spatiales pour l'évaluation des tracés alternatifs.

GIS in Environmental Assessment: A Linear Utility Case Study

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INTRODUCTION

In Ontario, Environmental Assessments are comprehensive environmental planning studies which are required under a) the Ministry of the Environment *Environmental Assessment Act* (EA Act) primarily for public sector developments, and b) under the Ontario Energy Board *Environmental Guidelines for Locating, Constructing and Operating Hydrocarbon Pipelines in Ontario* for energy facilities (pipelines, stations etc.). Environmental Assessments provide a rational framework to consider broad alternatives, environmental protection and conservation objectives before a development is given approval.

The EA Act requires the proponent of a project to supply information with regard to the purpose of the undertaking, alternatives to the undertaking, a description of the environment that will be affected, the effects that will be caused, the actions necessary to mitigate the effects, and an evaluation of the advantages and disadvantages to the environment of the undertaking (EA Act, section 5(3)). The scope of such studies entails inclusion of natural, cultural, and economic environment factors.

Ecological Services for Planning Ltd. (ESP) was involved in an EA study for a proposed linear utility route. ESP provided the environmental expertise on the natural environment and used GIS technology in the following study tasks:

- Database Creation to digitize and classify the environmental data as thematic layers;
- Route Identification involving an overlay data classification model;
- Route Evaluation to generate tabular output from overlaying routes with environmental data, and;
- Report Production to produce maps of the routes and the environmental data.

This paper will describe in more detail how GIS was used and the benefits and limitations of using GIS for each of the above study tasks. The information provided herein is of a generic nature due to the fact that the project is in an early stage of the approval process. The methods described illustrate the actual use of GIS technology in the exercise of routing a linear facility over a total distance of approximately 600 km. The data and study area however, are nonspecific.

DATA COLLECTION

Due to the broad definition of the term "environment" in the EA Act, a large amount of data must be collected in order to describe the natural, cultural and economic components of the environment to be affected. As a result, the data collection component of EA studies consumes a large portion of the available project budget and schedule. It is therefore important to ensure effective management of the data collection process. GIS enhances data management capabilities by providing tools for organizing, reclassifying, combining and updating the data that are collected.

The database required for the study was comprised of eight primary categories:

- human settlement and communities
- heritage resources
- cultural and scenic landscape resources
- recreation and tourism
- forest resources
- mineral resources
- biological resources
- agricultural resources

In linear utility EAs, a large amount of existing data is consolidated and analyzed. These data were primarily collected and stored through traditional mapping methods. For this project, the available background documentation was collected from many different agencies at different scales. The information was compiled by these agencies for their own purposes. Since the study area did not have all of the data available in digital format an environmental database was created by table digitizing the data collected from hard copy maps. One challenge was to compile the data in a form that could be digitized with GIS. To accomplish this, the data were transferred from the various secondary map sources onto a common base for digitizing. These maps were then table-digitized and imported into the GIS. The environmental data are summarized in terms of the format and source agency in Tables 1 through 7.

To further refine the data and prepare the information for the study, certain operations unique to GIS were required. For instance, it was necessary to translate Land Inventory (LI) classes into Resource Capability (RC) classes. The roads layer of the database was first buffered at a radius of 2km, and then overlaid onto the Land Inventory (LI) maps. Using a matrix overlay, all LI class 1, 2, and 3 lands within the buffer zone of the roads were classified as RC class 1, while LI class 2 lands outside of the buffer were classified as RC class 2, and all LI class 3 lands outside the buffer were assigned as class 3 Resource Capability.

Table 1: Human Settlement and Communities

Resource Feature	Source
built up	NTS maps, Municipal Official Plans, District Offices rural
settlement	NTS maps, Municipal Official Plans
settlement, recreation	NTS maps, Ministry of Tourism and Recreation
utility corridor	NTS maps
communication tower	NTS maps
airfield, heliport	NTS maps

Table 2: Heritage Resources

Resource Feature	Source
high potential for archaeological site	NTS Maps, Ministry of Communications and Culture
moderate potential for archaeological site	NTS Maps, Ministry of Communications and Culture
known archaeological site	MNR Sensitive Areas Report, MNR Regional Archaeologist

Table 3: Cultural and Scenic Landscape

Resource Feature	Source
river or valley land	NTS maps, Ministry of Tourism and Recreation
large lake landscape	
rugged terrain	
cluster lake landscape	
gently rolling topography	

Table 4: Recreation and Tourism

Resource Feature	Source
cottage cottage resort resort picnic site camp site trailer park boat catchment ski tow ski lift	MNR Regional and District Offices
canoe route	Ministry of Tourism and Recreation, Ontario Trails Council
provincial park	NTS maps, Parks Canada, MNR District Lands and Parks Supervisor
lake trout lake	Values Maps (1:100,000), MNR District listed trout lakes, remote MNR District Fisheries Management Plans

Table 5: Mineral Resources

Resource Feature	Source
active and proposed mining site	Municipal Official Plans, NTS maps
sand and gravel pit	Geological Compilation Series Maps, NTS maps

Table 6: Agricultural Resources

Resource Features	Source
Soil Capability for Agriculture	Canadian Land Inventory (1:100,000)
productive agricultural land	NTS maps, Agricultural Land Use Systems maps, Landsat TM imagery (1:10,000)

Table 7: Biological Resources

Resource Feature	Source
wetland	NTS maps, air photos (1:10,000)
fish spawning site migration stream waterfowl staging area eagle,osprey, heron nest	District Environmentally Sensitive Areas Report, District Values Maps (1:100,000), District Fisheries Management Plan
rare bird sites	District Environmentally Sensitive Areas Report, Federation of Ontario Naturalists Rare Breeding Program Database
deer concentration	MNR Wildlife Technical Reports
ANSI nature reserve sensitive area	District Environmentally Sensitive Areas Report
rare plant sites	National Museum of Natural History Rare Plants Database

Changes and additions were made to the database in response to quality control, agency review and public consultation processes. All information input after the initial data collection was given a unique code before it was integrated into the database. As a result, these changes were easier to manage than with traditional hard copy maps when querying the data necessitated the ability to distinguish between the updated information and the original information.

ROUTE IDENTIFICATION

Building on the database described above, existing methods of linear utility route identification were combined with GIS tools to provide an effective methodology for alternative route selection. The intention of this methodology was not to totally automate the route selection process within the GIS, but rather, to provide the study team with geographic information that would help identify routes in a group setting using expert opinion and visual analysis of the spatial pattern of environmental constraints.

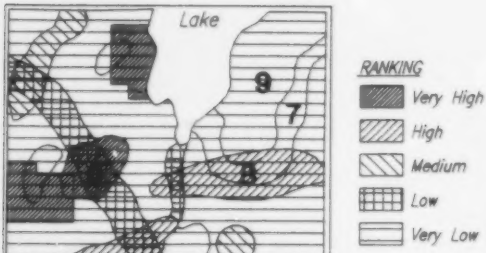
The environmental constraint mapping and associated route identification was based on rankings that were assigned to the environmental features contained in the database. The rankings were developed by the study team with input from public meetings and from various agencies. These ratings were determined based on the potential effects resulting from the utility corridor, the sensitivity of the resource, and the significance or value of the resource in terms of its rarity or uniqueness.

To create the necessary output, an algorithm was executed within the GIS to combine the resource features according to their rankings. The algorithm overlaid all data within the study corridor and compared the information at each location. For all comparisons the resource feature with the highest ranking was output to the model result. The map output from the algorithm reflected the constraint to utility rankings with the following five classes: Very High, High, Moderate, Low, and Very Low.

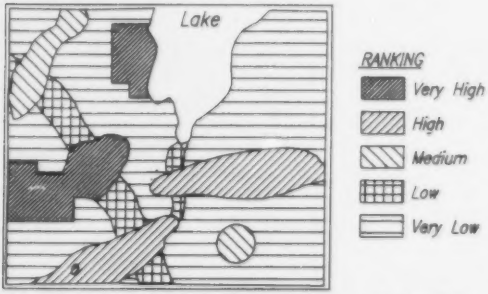
Figure 1A illustrates the complexity of the environmental data throughout the study area caused by the extensive overlap among features. The hatch patterns in the polygons indicate the rankings which, when overlaid without the algorithm, result in an overly complex map product. The model output result incorporating the algorithm is shown in Figure 1B. Polygon 6 had a Very High ranking; therefore it was imposed over lesser ranked features within its boundaries. Area 7 had a rating less than that of polygon 8 and was consequently overwritten by the higher ranked feature. Finally, polygon 9 has the same rating as polygon 7, so the two entities were merged.

The model simplified the visual pattern of the data considerably. This, allowed the study team to be able to work more effectively with the large

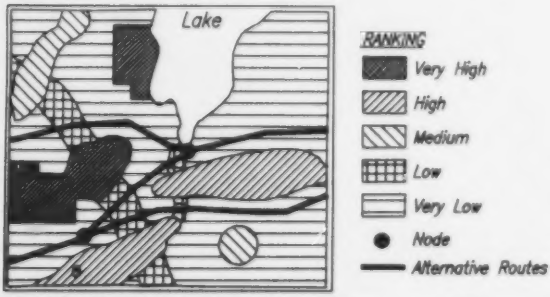
Figure 1: Route Identification Overlay Constraint Mapping



1A. Complex pattern of resource feature rankings.



1B. Simplified pattern after execution of algorithm.



1C. Identification of alternative routes

volumes and complex patterns of data originally presented in the problem. When necessary, detail was still available for reference from plots made of all of the individual resource features. Simultaneously using the modelling results and plots of each indicator permitted enhanced conceptualization of the landscape and thus an enhanced capability for route identification.

ROUTE EVALUATION

Following route identification, the comparison and evaluation of the alternative routes was undertaken with the assistance of GIS.

The routes were digitized such that a node was used to represent every point at which two or more route segments came together or where two or more route segments split from a single route segment (Figure 1C). Each route segment was assigned a unique code in the database. Since the routes in the vector database had no width, buffers were generated around each segment in order to create polygons which represent the areal extent of the potential route impacts.

A batch program was then written which overlaid each of the buffered segments with each of the mapped natural, cultural, and economic resource features. This resulted in the ability to develop reports of the area of constraint crossed by each segment for use in comparing alternative route segments. The area reports generated by these segment-constraint overlays were then merged into a spreadsheet table (Table 8).

The objective of route evaluation is to compare the alternative routes to evaluate which route will have the least impact on the environment. The evaluation was undertaken by the study team in a group exercise involving experts from the environmental disciplines in the study. The spreadsheet described above was the basis for the evaluation which used a pair-wise approach. Pair-wise evaluation involves choosing preferred segments between nodes across the study area; the preferred segments, in combination, constitute the preferred route at the end of the process.

Table 8: Sample Route Segment Comparison Report						
Segment	Resource Feature Crossed (Square km)					
	Built Up	Archaeology	Park	Wetland	Dune	
1-2	10	4	0	3	0	
2-3	12	3	0	0	0	
2-4	6	7	10	6	6	
4-5	3	5	0	0	2	
5-6	5	9	0	4	5	
5-7	5	6	0	4	3	
.						
.						
x-y						

CONCLUSIONS

As expected, there were significant benefits of using GIS in this project. Above all, the availability of the environmental database within GIS enabled the study team to manipulate a complex overlay process and derive comprehensive comparison data for use in selecting a preferred alignment. Manual methods would not have been able to accommodate this requirement as quickly or as efficiently as with GIS because the models used were flexible and easily edited for the repetitive overlay process.

GIS also proved to be effective for accommodating new or revised data and new or refined alternative routes. Since the EA process involves a dynamic ongoing process of dialogue with agencies, the proponent, the public and within the study team itself, this flexibility to respond to change was invaluable.

The largest component of the cost of utilizing GIS for this routing project was related to the digitizing of the environmental database. With increasing availability of digital information within the various resource sectors, costs can be expected to be significantly reduced in the future.

Localizing Forest Management Using GIS and Remote Sensing: The Research Agenda of the Industrial Research Chair in Geomatics Applied to Forestry

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Abstract

Historically, quantitative Forest Management tools have become increasingly scientific and localized. With the sophistication of existing digital spatial technologies (DSTs) typified by geographic information systems and digital remotely-sensed data, it may be possible to add a spatial component to present-day Forest Management tools. Such a step would further the goal of conducting forest management using locally-reliable data and analysis. The current barriers to this involve limitations of existing data, statistical techniques, and utilization of information about spatial errors.

L'Utilisation du SIG et de la Télédétection à Faire l'Aménagement Forestier plus Localisé: le Programme de Recherche de la Chaire Industrielle en Géomatique Appliquée à la Foresterie

Résumé

Historiquement, les outils numériques pour l'aménagement des forêts ils ont devenu plus scientifiques et plus localisés. Avec la rafinnement de technologies numériques et spatiales qui existent — c'est à dire, les systèmes d'information géographique et les télédétection — peut-être c'est possible ajouter un élement spatial à des outils actuels de aménagement forestier. Une démarche comme ça servirait le but de conduire l'aménagement forestier en utilisant les données et les analyses qui sont sûr pour une localisation donnée. Les barrières actuelles impliquent des limitations des données existantes, des techniques statistiques, et l'utilisation de connaissances des erreurs spatials.

1. INTRODUCTION AND PERSPECTIVE

A. FORESTRY RESEARCH PRIOR TO THE 1980S

Until the late-1800s in North America, forest "management" was generally synonymous with "exploitation." Human populations had not yet swelled to a point at which forest resources were considered to be a limited resource which must be utilized wisely to ensure the existence of adequate wood supplies in the future. However, by the early 1900s it had become clear that North America's wood supply was, indeed, limited. Thus if future supplies of wood products were to be available, foresters needed to adopt a philosophy of "perpetual management" rather than "limitless exploitation."

This philosophical change was (arguably) the start of the modern discipline that is today called Forest Management. In a sense, this new philosophy was an adaptation to forestry of ideas already embedded in commercial agriculture. That is, instead of merely being willing to harvest a crop (wood) as grown by Nature, the need for human intervention in the forest was recognized in order to improve the quantity and quality of available wood. At the same time, humans began to understand the need for improved stewardship of forest land and the responsibility inherent in the utilization of natural resources. As a result, embryonic "seat-of-the-pants" Forest Management began to yield to a desire to make the subject more "scientific."

Thus in the 1930s a variety of quantitative forest management aids began to appear. These included tools such as site index curves for measuring site productivity, yield tables for estimating the future wood volume of existing forest stands, and volume tables for determining the amount of merchantable volume in standing trees. Initial techniques were relatively crude and methodologies for the creation of these tools were not standardized. Consequently, the years following the 1930s saw improvement and standardization in the ways these were created, and a subsequent increase in the reliability of each.

By the 1960s, many problems inherent in the development of these early quantitative forest management tools had been resolved. Furthermore, researchers began to recognize that certain limitations were related to the quantity and quality of data available, rather than to existing analytical techniques. Thus, although some research continued on these and similar subjects, a large number of researchers began to shift their emphases. Instead of trying to build better management tools, considerable effort was devoted to trying to obtain better information about the forest resource.

At this point, considerable effort began to be spent on refining forest inventory. Researchers sought to determine things such as the "optimal" sample size, the "best" inventory design, and the "ideal" field procedures. A critical part of this work was the utilization of aerial photography to improve forest inventory estimates. In fact, a number of researchers focussed specifically on how to obtain the maximum amount of information from aerial photographs while minimizing the amount of relatively expensive field work required. Arguably, it was at this point that remotely-sensed data (in the form of aerial photographs) began to be commonly viewed as an indispensable part of forestry data collection efforts.

Around the start of the 1970s, a significant revolution occurred as, for the first time, powerful computers became readily available to forestry researchers. One arena in particular whose development accelerated greatly because of this was growth and yield modelling. In one sense, growth and yield modelling was a catalyst for the integration of existing management tools, as well as a gateway to the development of increasingly sophisticated mathematical models. Another subject which benefitted from the widespread availability of computers was Operations Research. At this time, optimization techniques such as linear programming began to be applied to Forest Management in harvest operations, forest fire control, and others.

B. PERSPECTIVE ON PRE-1980S RESEARCH

Each of the "eras" of forestry research mentioned in the previous section has advanced Forest Management as a science in an important way. Early graphical and tabular management tools initiated in the 1930s provided the ability to assess the amount of wood in an existing forest stand. Forest inventory techniques refined during the 1960s enabled foresters to estimate reliably the amount of wood present on a relatively large area. Growth and yield models integrated early management tools with forest inventory data to allow the characteristics of an existing forest to be projected into the future under a variety of management scenarios. Linear programming techniques provided a way to determine and evaluate the optimum way in which an existing forest can be harvested, regenerated, and treated silviculturally.

With this perspective, it is evident that a number of common themes run through forestry research from the early 1900s to the 1970s. First, management tools have become more quantitative and scientific. Second, as these have become more sophisticated, each has been able to utilize more ecophysiographical factors to estimate quantities such as site quality or forest volume. Third, each "generation" of research has relied heavily on previous successes (and failures) to produce state-of-the-art management systems and tools. And, finally, though not an explicit goal, the evolution of forestry research has led to an ability to conduct increasingly localized forest management.

This latter point is the subject of this paper. By "localized forest management" we mean planning the utilization of the forest over large areas using tools and data which are reliable for a relative small area. For example, rather than knowing the mean volume for Type A over a 1000 ha forest, it is desired to prepare forest plans using the volume for a specific piece of Type A (an individual stand polygon) in the southeastern section of the forest. Similarly, rather than knowing, for example, the wood volume that will be produced 20 years from now if a silvicultural treatment is applied to half of a forest at the present time, it is preferable to know how much volume will result **and** where it will be located if a specific set of stands are treated. The inherent difficulty in being able to do this is that previous data collection procedures and analytical management methodologies have focussed on questions of "How much...?" and "What will happen on this forest if...?" That is, existing technology -- hardware and analytical techniques -- and data collection costs have necessarily precluded the use of location from most modern forest management tools. We believe that the next questions that the field of forestry research has the potential to answer and must address are questions of "**Where** should...?" and "What will happen **here** if...?"

C. FORESTRY RESEARCH: 1980S TO PRESENT

By the mid-1980s, with the advent of desktop microcomputers, another technological revolution had progressed considerably. At the same time, microcomputer software and hardware had become increasingly sophisticated while its price continued to decrease. This has led to the development and application to forestry of computer-intensive subjects such as artificial intelligence and expert systems. The focus of this paper, however, is another discipline whose development accelerated with the introduction of microcomputers: digital remotely-sensed data and geographic information systems (RS/GIS). .

The digital analysis of remotely sensed data for forest management is a relatively new technology. Research in the 1980's focussed largely on the use of satellite remote sensing for carrying out large scale surveys for activities such a long range planning and the production of synthesis maps showing broad classes of species at low resolution [Beaubien, 1983; Leckie, 1990]. The late 1980's brought new imaging sensors on airborne platforms with high spatial resolution and larger dynamic range than aerial photos [Till *et al.*, 1983]. New digital sensors are planned for the 1990's which provide spatial coverage close to that achieved with aerial photography [Neville and Till 1989]. Images acquired with these and other modern sensors have the potential of replacing

the older, analog technology and hence increasing the efficiency of forest map production, especially through direct interfacing with GIS technology.

GIS is likewise relatively new to forest management. This is most obvious when one considers that the largest source of data for GIS is found in existing paper maps. For the most part, practitioners are still "converting" paper maps to their equivalent electronic form and have not yet moved on to the creation of electronic maps directly (for example, directly from image analysis).

Both GIS and the analysis of remotely sensed images should allow one to answer the question "Where?" in Forest Management. (Collectively, we refer to the data, hardware, and software used for the collection, storage, retrieval, and analysis of numerical, geographically-referenced data as "digital spatial technologies" or DSTs.) However, a myriad of problems exist before this can become reality. Three specific problems will be discussed here which we believe to be the most immediate barriers to the adaptation of existing forest management tools to a spatial framework using DSTs: availability of appropriate data, knowledge of suitable statistical techniques, and inability to quantify and utilize spatial errors. These problems are presently targetted by the research program of the Industrial Chair in Geomatics Applied to Forestry.

2. DATA

Research involving forest inventory has led to a relatively standardized methodology in North America. Usually, the first step is a photo-interpretation-based stratification of an area into distinct forest types. The goal of this stratification is to divide a relatively large population into relatively uniform sub-populations (strates in Québec) in order to increase the precision of subsequent population estimates of volume. In statistical terms, the goal is to minimize within-group variance and to maximize between-group variance. After stratification, a sample size for on-site data collection is determined and individual samples are distributed among sub-populations (strates) based on the variance, importance, and/or size of each strate. The cost of data collection can also affect the number of samples in each strate. After determining the distribution among strates, each sample plot is located on a map and established on the ground. A field crew then collects all data desired.

In this process, if it can be assumed that each sub-population is "perfectly uniform," then the location of a plot within a particular sub-population is unimportant. However, it is well-accepted that, for example, a linear arrangement of plots which follows existing topography is not desirable. It is also considered unwise to place all samples for a particular sub-population within a single polygon if, for example, 20 polygons of that sub-population exist in the forest population. These examples suggest that, despite stratifying a forest into relatively uniform groups, the specific location of samples does remain important.

Therefore, the first question that must be answered relative to using existing forest inventory data to localize forest management is "Are the data collected for a strate in one location suitable for the same strate in a different location?" Current forest inventory procedure assumes that they are. Or, to be fair, this assumption must be made if conventional forest inventory data are to be used to make forest-wide estimates. If this is true, then existing forest inventory data can be adapted to DSTs relatively quickly because forest estimates obtained at a given location within a particular strate will be applicable to other locations of the same strate.

Research Priority 1: The spatial change in forest parameters within a given strate must be examined and fully characterised (Figure 1).

For those strates where forest parameters are found to vary significantly with location, new ways to collect locally-reliable forest inventory information are needed. One possible way to do this is

through the use of digital remotely-sensed data. New sensors are continually collecting digital data with increasing spectral and spatial resolution, improved hardware is allowing more complex analysis, and better computer-based analytical techniques are constantly being developed. For example, whereas early Landsat satellite images provided for the identification of broad vegetative classes only, work is ongoing to determine if certain bands of radar can produce reliable estimates of forest biomass [Sader, 1987]. If this work is successful, potentially it will be possible to produce estimates of forest volume "automatically" with a minimum of costly ground-based data collection. Also, analysis of high resolution digital airborne data may lead to the ability to identify the species, age, height and local density of individual trees [Gougeon and Moore, 1989] or the percent stocking of regenerating cutovers [Edwards *et al.*, 1991]. Data on individual trees could then be generalised to obtain continuous maps rather than category maps showing species location. This kind of map is likely to be much easier to produce from digital imagery than the maps produced by human photo-interpreters. If new management techniques for exploiting this information can be developed, in the long term such locally-reliable results may also be more useful.

Research Priority 2: The ability of remotely-sensed data to produce locally reliable forest estimates must be examined as a supplement to, and possibly even a replacement of, existing forest inventory procedures.

The single largest obstacle to understanding and using remotely sensed data at this level of localisation is validation. Most of the information which could be used for validation does not exist at the level of individual trees. Even ground inventory data does not give information about individual trees. Furthermore, even if information was available on isolated trees, they cannot readily and unambiguously be identifed in remotely sensed imagery. Geopositioning can help, but experience to data indicates that even with GPS position to less than a meter resolution, locating sample plots is still difficult. Hence new methods of validating very precise local information must be developed, methods which are economical as well as being reliable.

Research Priority 3: New ways of validating local information using both existing information sources and new but not too costly sources must be explored.

A second possibility exists for obtaining locally-reliable forest inventory data, a method which might also be used to help validate the remotely sensed data. It may be possible to develop procedures to collect these data as part of conventional normal forestry operations with little additional effort. For example, when a forest is harvested, the first step is generally to clear the roads which will access the area. In Québec the wood cut from the roads is harvested, scaled, and taken to a factory for processing. If the wood were scaled by strate, and the area of the road from which it was cut were known, locally reliable forest inventory data could be obtained (Figure 2). The only additional cost of such a scheme would be piling the wood by strate and measuring the road length of the strate from which it came. (Road width could be assumed to be fairly constant, and/or spot-checks of road width could be conducted.) For such an approach, a long-term effort would clearly be required in order to establish a spatial "data dictionary" for a large area using a GIS. However, once established, a minimum of effort would be required to maintain and update such a system. Prior to DSTs, it would not have been possible to think of creating such a management tool. Even now, it remains unclear whether existing DSTs in general, and GISs in particular are suitably developed for the storage and manipulation of such data.

Research Priority 4: Operational procedures for the collection of locally-reliable forest inventory data must be developed.

Finally, the density of forest inventory data collected must be examined. As noted, data are collected currently to be "forest-reliable" and, in general, are well-suited for managing "average conditions" within each strate. However, some strates will have enormous within-strate variability

while others are likely to be uniform over a large region. This varying uniformity of strates and individual stand polygons has tremendous implications for estimating the area of each strate within a forest, as well as the amount of wood volume within each. To make these data locally-reliable, it may even be necessary to increase the number of samples while (possibly) reducing the size of each in order to maintain present costs.

Research Priority 5: To determine the necessary sample density to obtain locally-reliable forest inventory data, the within-strate and between-strate change in various forest parameters must be examined for a variety of conditions.

3. STATISTICAL TECHNIQUES

Paralleling trends in other research disciplines, the development of analytical tools in forestry has relied heavily upon the use of parametric statistics. Principal among these are regression analysis and the analysis of variance. However, the use of parametric techniques requires that a number of a priori assumptions concerning the data be satisfied. The most common of these are that each observation is independent of the others (which is almost always violated in the construction of growth models), variance along a regression line is homogeneous (almost always violated when biological data are analyzed), and prediction errors are normally and randomly distributed (rarely verified). In the adaptation of these statistical techniques to the analysis of spatial data, these assumptions become even more dubious. The principal reason for this is that, when distributed spatially, almost everything is interrelated, non-uniform, and non-random.

Another class of problems exists because of the general nature of map-based data. Most existing analytical techniques in forestry research utilize continuous data. For example, growth models project quantities such as basal area or stand diameter into the future. However, spatial data are never continuous when stored as a map. Thus existing analytical procedures for these geographic data are generally based on discrete variables -- e.g, 5 m elevation classes. Furthermore, most forestry research is based on known, unchanging observation units -- individual trees, for example, or 0.1 hectare sample plots. However, the base unit on a map is generally a polygon. In a natural forest system, the spatial characteristics may change over time (Figure 3). This causes problems statistically, and also in how these polygons can be stored and modelled using DSTs. To adapt existing forest management tools to a spatial framework, analytical techniques which utilize discrete data must be explored to enable the modelling of the time-based change in the attributes, shapes, and sizes of map-based polygons. Furthermore, spatial models must be able to account for the spatial dependency among geographic entities -- something that is rarely included in existing forest management tools.

Research Priority 6: Existing and alternate data structures and operations for GISs must be explored for the use of locally reliable forest inventory data.

Statistical techniques are not the only problem, however. As noted, maps are designed to store discrete data. As a result, with existing DSTs, geographic data are stored either as a series of grid cells each of which is one and one class only, or as a series of sharp lines which separate distinct regions. (This will also be discussed later in "4. ERRORS.") Conversely, "real world" forestry data are continuous. For example, trees grow continually in minute increments. Ecological succession occurs continually but gradually. A probabilistic approach may offer a viable bridge between these two. As envisioned, a predictive system for DSTs would not merely assign an entity to one or another class. Instead, at each time period of interest, the probability of a given entity being a particular class would be assessed. Thus the result of a spatial predictive model, as envisioned, would be a surface representing the probability that a given map entity -- raster grid cell or entire polygon -- would be assigned to a given class at some point in the future. A potential problem with this is that such probability surfaces may be difficult for humans to interpret.

However, as each entity could be assigned to a class in a fashion representative of its probability and a thematic map produced for human comprehension. The difference between this and the usual practice is that the thematic map used for human interpretation would not be used as "data" in subsequent processing -- only the underlying probability surfaces would be used for further analysis.

Research Priority 7: Statistical modelling techniques for discrete map-based data must be developed. This includes examination of existing aspatial statistical techniques, the use of probabilistic techniques for predictive maps, and the examination of spatial relationships among map-based entities.

4. ERRORS

In most scientific research, an assumption is made that a parameter of interest can be measured "without error" (subject only to the limitations of the equipment used for measuring). Relative to this, a number of DST researchers have concentrated on the analysis and effects of errors of digitizing, map registration, and/or satellite image referencing. It is argued here that, in forestry, these errors are generally relatively unimportant (except for obtaining positions for validation purposes) and are akin to errors of "equipment limitations." This is not to say that these are unimportant in all disciplines. Indeed, in those mapping subjects which utilize political and/or man-made boundaries -- we call these "razor sharp boundaries" here -- these errors are the major categories with which one must be concerned. That is, in such situations each boundary is a line which has no width and two identifiable endpoints which do indeed separate two distinct entities. Furthermore, that line can be physically located on the ground if necessary.

This is one of the most subtle yet most important differences between maps of natural phenomena, and maps involving human geography. It is especially important to note that the design of most DSTs -- especially GISs -- is based on concepts inherent in human geography. Notably, the idea of razor-sharp boundaries is not applicable to natural forest stands. In forests, not only is the "true" location of any boundary in doubt, but the very existence of a boundary may be questionable. Any forester who has walked through the woods holding a map which was developed through a reliable photo-interpretation process knows the difficulty of actually identifying forest-type lines on the ground. Furthermore, natural forest types rarely change abruptly as one moves through the forest. Rather, one will notice that one has gradually moved into a different forest without being able to identify where the change occurred. Even the "distinct" break between a clearcut and a mature forest stand may be difficult to locate precisely on the ground. This suggests an idea for natural forest stands which we call "fuzzy boundaries" (Figure 4).

We call boundaries fuzzy when one (forest) type gradually becomes another and the exact line between the two types cannot be identified on the ground without "considerable" error. In this sense "error" is equivalent to "uncertainty" in that there is a level of confidence associated with the existence and location of each boundary, and with the polygon type identified on either side of a boundary. This contrasts with maps of certain other phenomena for which boundaries are definite and only the polygon type is uncertain. Thus we believe that the concept of "fuzzy boundaries" in forest stand maps necessitates the examination of two separate but related errors.

The first is boundary error which exists if a boundary has been identified which does not really exist, or if an existing boundary has not been identified. The situation in which a boundary which definitely exists but is located in the wrong place is also in this category. The second type is category error which occurs when boundaries have been correctly identified, but the polygon on either side of the line has been mislabelled. Both types of errors have long been recognized in the classification of remote sensing data, although only category error is usually measured. A

boundary error might involve the failure of an automated classification procedure to distinguish between two fields, whereas a category error might involve the mislabelling of a corn-field as a wheat-field. In a forestry setting, both errors are related and the probability of observing one or the other depends largely on the characteristics of adjacent forest stands. This will be discussed shortly.

To understand the current inability to incorporate these types of errors into DSTs, one must examine the historical background of maps. The existing form of maps has been guided largely by the technical limitations inherent in pen and paper, and by limitations of human ability to interpret "pictures." Thus present-day thematic maps are composed of a series of polygons which are drawn as having razor-sharp boundaries. Generally, these maps are satisfactory in that they are easy to produce and easy to understand. Furthermore, if polygons are well-defined -- provinces or townships -- the units represented on a map are "humanly-meaningful" entities. However, with such maps it is difficult to represent a geographic surface of a continuous variable. For example, "topographic maps" which show a continuous variable -- elevation -- may be viewed as little more than a series of long, narrow polygons which place elevation into discrete classes. Furthermore, for some variables (such as population density) the map scale can radically change the content of the map.

The point of this discussion is not that existing maps are inherently flawed. With pen and paper and human comprehension, it is understandably necessary to represent the world as a series of discrete polygons which have razor-sharp boundaries. However, the point here is that such a map concept is poorly suited for the spatial adaptation of existing forest management tools in order to localize forest management. Simply, the existing form of physical maps has inherent limitations for modelling forest conditions over space and time.

We believe that the technological sophistication of DSTs allow a redefinition of map concepts to better facilitate spatio-temporal modelling. We further believe that the most immediate need in forestry is the ability to incorporate uncertainty (or "error") into forest stand maps for storage, analysis, and modelling. The first step in this effort is the determination of how to measure boundary and category error. This can start by examining selected forest parameters in specific controlled settings. For example, it is intuitively reasonable to expect that the boundary between two highly variable forest stands having similar mean densities will be fuzzier than between two extremely uniform stands with widely different mean densities. Similarly, it should be possible to infer the likelihood of a category error for various positions within a stand polygon or a given shape. In a circular stand, for example, the smallest chance of category error would seem to exist at the center. Whether or not this is true must be evaluated.

Research Priority 8: Forest parameters must be examined and appropriate measures must be developed to quantify boundary and category errors.

5. PROJECTIONS FOR THE FUTURE

We believe that existing DSTs must be altered considerably for application to forest management. An "ideal" system will have an error map associated with each thematic map stored, some of which will result from more sophisticated remotely-sensed data and analysis algorithms. In forestry, operations such as "Overlay" which superimposes one supposedly precise map on another should largely disappear and give way to operations which work across fuzzy polygon boundaries. This will only occur if emphasis in the analysis of forest stand maps shifts from the individual polygon to the boundary between two adjacent polygons. (We call this unit a "twain.") This shift can be facilitated by the development of spatially-based probabilistic modelling techniques. These techniques will allow foresters to ask questions of "What will happen if...?" just as current aspatial management tools do. However, the answer to these queries will be a map surface which shows

the probability that a given outcome will occur at a particular location rather than provide a deterministic result (Figure 5). To convert these surfaces to something more useful for presentation and human interpretation, the development of these modelling techniques will have to be accompanied by a robust set of class assignment techniques to produce simplified thematic maps of a form similar to that which exists presently.

6. CONCLUSIONS

Three major barriers exist which hinder the use of DSTs for locally-reliable forest management: available data, suitable statistical techniques, and the use of spatial errors. Data limitations possibly may be overcome by using smaller forest inventory plots but more of them, collecting data as part of forest operations, constructing and maintaining long-term spatial data dictionaries and by increasing the use of high resolution digital remotely sensed data. Non-traditional statistical techniques must be examined which can accommodate discrete (categorical map class) variables, and which are robust enough to tolerate some violation of underlying assumptions. Perhaps non-parametric statistical techniques must be used. The initial step in the use of errors is to be able to quantify different types of uncertainty inherent in forestry maps. After this, new analytical operations which utilize error information as useful knowledge can be developed.

7. ACKNOWLEDGEMENTS

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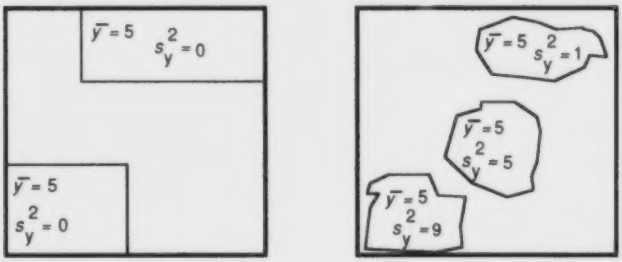

Figure 1. Populations where characteristics do not change with location (left) and where variance changes (right).

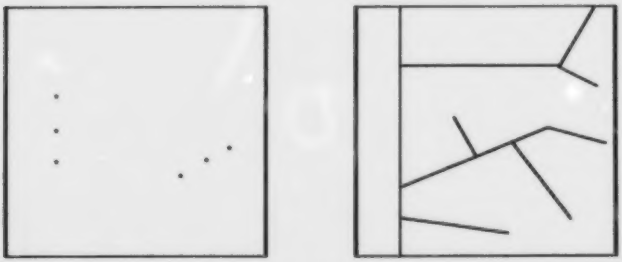

Figure 2. Isolated sample points for global estimates (left). Potential road network sample for local estimates(right).

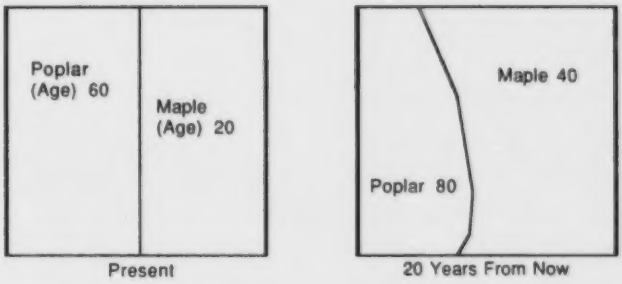

Figure 3. Change over time in attributes and polygon form.

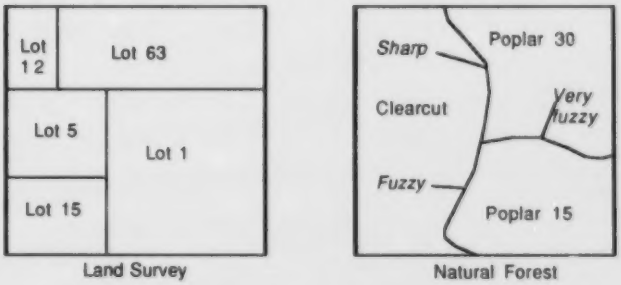

Figure 4. Map whose "real world" boundaries **are** sharp (left) and areas whose "real world" boundaries **are not** sharp. Note that the map representation is the same for both.

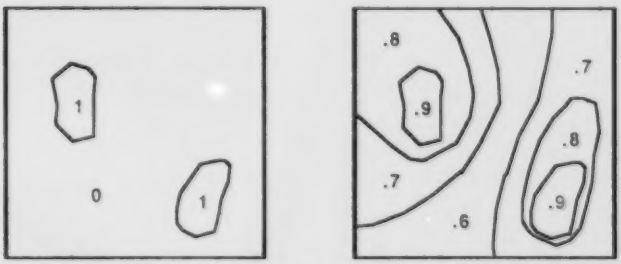

Figure 5. Deterministic (left) and probabilistic (right) maps of "suitable locations."

Network Access to Environmental Data

by

Geographic Information Systems

Environmental managers are demanding up-to-date decision support information with GIS systems providing many new integrated information products. The current GIS workstation system design is creating a data bottle-neck resulting for the GIS specific data base structures which required data conversions and delays in inputting up-to-date data required for decision support. Environmental data are often organized by traditional scientific fields of expertise; the data bases are updated and maintained at centres of expertise located across Canada.. The objective is to improve the access to the environmental data available at these centres for workstation manipulation into decision support information. The data base and network technologies are fast maturing to provide user workstations up-to-date data required by environmental decision makers. The recommended approach is to have functional calls to these environmental data bases via computer networks linking the user GIS workstation to the most recent data required for decision support product generation. The implementation would provide the framework for GIS workstation suppliers and data publishers to develop the necessary software tools to provide managers a method for systematic on-line access to these data sets to prepare time critical environmental information for decision support.

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Accès réseau aux données environnementales par les systèmes d'information géographique

RÉSUMÉ

Les gestionnaires de l'environnement ont besoin, pour la prise de décisions, d'informations à jour, et les SIG fournissent de nombreux produits intégrés d'information. La conception actuelle du poste de travail SIG crée un engorgement des données qui découle des structures spécifiques à la base de données SIG, lesquelles exigent des conversions et entraînent des retards dans l'entrée des données à jour nécessaires à la prise de décisions. Les données sur l'environnement sont souvent organisées selon les champs scientifiques traditionnels; par ailleurs, les bases de données sont mises à jour et entretenues à des centres d'expertise situés dans tout le Canada. L'objectif est d'améliorer l'accès aux données environnementales disponibles dans ces centres pour les manipuler aux postes de travail en vue de la prise de décisions. Les technologies des bases de données et des réseaux évoluent rapidement afin d'offrir aux décideurs de l'environnement des données à jour aux postes de travail. L'approche recommandée est de pouvoir appeler de façon fonctionnelle les bases de données environnementales en établissant un lien de réseau informatique entre les postes de travail des utilisateurs de SIG et les données les plus récentes nécessaires pour la génération de produits à l'appui du processus décisionnel. Une fois mis en place, le réseau donnerait, aux fournisseurs de postes de travail SIG et aux éditeurs de données, le cadre d'élaboration des logiciels qui offriront aux gestionnaires une façon d'obtenir un accès en direct systématique aux ensembles de données avec lesquelles ils prépareront les informations environnementales à jour à l'appui de la prise de décisions.

THE CITY AS A SURFACE: A FRACTAL INVESTIGATION OF AERIAL IMAGERY OF SAINT LOUIS, SENEGAL

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Abstract

Over the past few years, a debate has developed concerning the application of fractal geometry to apparently non-fractal geographic data, especially urban data. This study takes this debate as a point of departure. Scanned aerial photography of Saint-Louis is considered as a surface; the fractal dimension of that surface is measured. Essentially, the texture of the image is analyzed in the application of this procedure. This process is repeated on imagery at various resolutions.

The study determines that the city, when viewed in this manner, does not conform to the fractal model, since it is not self-similar throughout the range of resolution considered. Nevertheless, the fractal categorization of urban neighbourhoods corresponds in many ways to a visual interpretation of the imagery, in addition to providing a wealth of information to augment that qualitative interpretation. Meaningful results are thus obtained when using the fractal model as a reference point against which urban data may be evaluated, even when the data are not fractal.

RÉSUMÉ

Depuis quelques années, la controverse entoure la question de l'application de la géométrie des fractales à des données géographiques apparemment non fractales, tout particulièrement dans le cas des régions urbaines. C'est le point de départ de notre étude. On considère la photographie aérienne balayée par scanner de Saint-Louis, au Sénégal, comme une surface et l'on en mesure la dimension fractale. Essentiellement, la texture de l'image est analysée lorsque la méthode est appliquée. L'opération est répétée à différents degrés de résolution.

L'étude a permis de déterminer que, vue de cette manière, la ville n'est pas conforme au modèle de fractale, car il n'y a aucune récurrence aux degrés de résolution considérés. Néanmoins, la classification fractale des régions urbaines correspond sous bien des aspects à l'interprétation visuelle de l'imagerie, en plus d'apporter une kyrielle de renseignements utiles dans l'interprétation qualitative. Le modèle de fractale comme base de comparaison dans l'évaluation des données urbaines, même si celles-ci ne sont pas fractales, donne donc des résultats utiles.

Introduction

This study seeks to answer two questions: one, does the city, as a physical entity, conform to the fractal model; and two, can fractal geometry be used as a spatial language to describe and to distinguish between neighbourhoods which, on aerial imagery, are obviously different to the human eye. The study was conceived as a response to a debate concerning the nature of urban form, and the relationship between urban form and fractal theory. The following discussion of fractal theory will provide a theoretical background. A method for the evaluation of aerial imagery using fractal geometry is then outlined. The results of a fractal analysis of aerial imagery of the case-study city, Saint-Louis, Senegal, will be presented.

Fractal Geometry

The term *fractal* was coined by Benoit Mandelbrot from the Latin *fractus*, implying fragmentation or irregularity (Mandelbrot 1983: 4). The domain of fractal geometry falls between the points, lines and planes of Euclidean geometry, describing the way that objects fill space in a new manner, as illustrated in figure 1. Two fractal curves, 1b and 1c are portrayed between the one-dimensional line and the two-dimensional rectangle. The fractal dimension, D, relates to the jaggedness of the figure, to the degree in which the figure fills space, with a higher values of D indicating a more jagged figure. Similar logic applies to fractal surfaces, where the fractal dimension lies between two and three, depending on the roughness of the surface, that is, on the way in which the surface can be considered to fill volume (Goodchild and Mark 1987: 269).

Mandelbrot has defined a fractal simply as "a shape made of parts similar to the whole in some way" (Mandelbrot, cited in Feder 1988: 11). Such a definition implies self-similarity, pattern-within-pattern, so that at any level of resolution a truly fractal object resembles itself at any other level of resolution (Voss 1988: 71-73). One may conceive of fractal applications where absolute self-similarity might apply (crystallography for example), but in most applications self-similarity is either *statistical*, in that the object or process in question is fractal only when considered in aggregate terms, or *scale-bound*, such that the fractal model applies over a limited range of scales (Mandelbrot 1983: 19).

Fractal Geometry and Geographical Phenomena

The concept of fractal geometry has found application in many fields, ranging from particle physics (Kaye 1988) to physiology, music ,and economics (for a summary of applications in various fields, see West and Shlesinger 1990) . Within geography, there has been considerable debate regarding fractal applications, which range from Central Place Theory, where Cristaller's work is recast as a subset of fractal theory (Arlinghaus and Arlinghaus 1989), to cartographic line simplification (for example, Broscoe and Prashker 1991; Carstensen 1989; Longley and Batty 1989).

Much of the controversy regarding the application of fractals to geographic phenomena stems from the implications of the concept of self-similarity. For example, if one were to view an air photograph of a truly self-similar world, it would not be possible to determine the scale of the photograph, since at any scale,

the world would resemble itself (Goodchild and Mark 1987: 268). With real-world geographical data, this condition is most often not the case; an indicator of scale, either natural or cultural, is present. This consideration renders the fractal model inappropriate for many researchers (Lam 1990: 189).

Such a rigid view of fractal application, however, seems to miss the point. Mandelbrot himself devotes considerable attention to scale-bound fractals and their application (Mandelbrot 1983: 146-165). Increasingly, the fractal model is being used as a guide, against which one can compare geographical `reality' (Goodchild and Mark 1987: 275; Lam 1990; Mandelbrot 1983: 18-19; Pentland 1986). This is the general context for a specialized debate regarding the application of fractals to urban phenomena.

Applications of Fractal Geometry to Urban Phenomena

Attempts at linking urban theory and fractal theory have been limited. Only Michael Batty and Paul Longley, in occasional collaboration with other researchers, have consistently explored these links (Batty 1991; Batty and Longley 1987; 1986; Batty, Longley and Fotheringham 1989; Longley and Batty 1989; Longley, Batty and Shepherd 1991). Others have questioned the validity of such research, based on the circumstantial nature of the evidence linking the two fields and the apparently partial conformity of urban form to fractal theory (MacLennan 1988: 70-71). The methodological path chosen by Batty and Longley, however, precludes an adequate response to such questions. The digitized urban boundaries upon which Batty and Longley base much of their work certainly do not indicate what one might consider a basic unit of urban physical structure, for example, a building or a city block. Their focus is on the region and the city as a whole; they do not investigate the city at the scale of the neighbourhood, where Batty himself hypothesizes a poor fit of the fractal model (Batty 1991: 48).

Is The City Fractal?

This brings us to the first goal of this study: to determine if city form, at the scale of the neighbourhood, conforms to the fractal model, that is, to determine whether it is self-similar. The proposed method is to consider, for the chosen city of Saint-Louis, scanned monochrome aerial imagery as a surface, where the grey tones of the photograph represent the Z dimension of the surface. The fractal dimension of that surface is then measured, evaluating the texture of the image, where texture is defined as variability in tone over a given area (Mather 1987: 312). This follows a long, albeit empirical, tradition of the use of texture as a aid in air photo interpretation (Adeniyi 1983: 547). The selected method of calculation, the `blanket' method (Peleg et al. 1984; Dellepiane et al. 1988), allows for the calculation of the fractal dimension of a small window of the image, so that fractal surfaces, arrays of local fractal dimension values which relate explicitly to locations on the original images, can be obtained. Saint-Louis was chosen as the study area since the city presented very marked contrasts in morphology between neighbourhoods, with a distinct colonial sector and examples of `organic' growth on the periphery.

Method

For each of seven neighbourhoods, digital images, each approximately 480 by 512 pixels, were obtained from 1:4000 scale monochrome aerial photography of the city, through a process of scanning. The per pixel resolution of each image was identical, within the limits of the scale variation of the original photography. A process of histogram equalization was then applied to the images, so that in statistical terms, the spectral character of each image was standardized.

These images were chosen to represent the extremes in the variation of city morphology within the city. Three images were selected from the colonial sector, which was rebuilt in the 1860s to reflect the position of Saint-Louis as capital (Winters 1982: 140; Vennetier 1976: 20). The morphology of this sector is characterized by regular geometrical patterning, where the streets are laid out in a grid pattern and the buildings are aligned to the street. One image was obtained from Guet N'Dar, an established `indigenous' neighbourhood, also rebuilt to a grid about the same time as the colonial sector, but with smaller buildings (Faidherbe 1899: 78-79). Two images were obtained from the rapidly growing settlement of Pikine, a `bidonville' (Ba, N'Diaye and Soumah 1980: 44) founded on the periphery of the city around 1960, which is characterized by an irregular transportation network, `haphazard' building alignment, and a polyglot ethnic composition. Pikine has been described as totally lacking in spatial organization (Camara 1969: 252). Both Pikine and a section of Sor, from which the seventh image was obtained, are examples of `organic growth', a concept which is intuitively simple to grasp but difficult to define. A.E.C. Morris characterizes this "*unplanned* evolution of a town" as conforming to "some *indefinable* natural pattern" (Morris 1972: 9, emphasis added). This seventh image, obtained from an older neighbourhood than Pikine, shows `organic growth' within the confines of a grid-based road network.

Using the `blanket' method and a nine-by-nine pixel moving window, the fractal dimension (D) of the area on the digital image within the window was measured. The value of D was somewhat arbitrary, since the x and y values were pixel locations but the z values were measures of tone. Thus the actual D value was dependent upon the relationship between the units assigned to the three axes. The method was consistent throughout the study so that comparisons between images could be made. This D value was placed at successive locations on a `fractal surface' which corresponded to the centre pixel of the window on the original surface. Thus a matrix of fractal values was created. A similar process was used to obtain a `correlation surface', which measured the fit of the fractal model within the window, expressed in terms of an r^2 coefficient. These derived surfaces could then be compared visually as well as in quantitatively.

The generated fractal surfaces reflected the character of the original surface. The fractal analysis process acted as an edge detector on images with relatively large buildings (the colonial sector and Pikine) but detected cloudlike areas of dense settlement on images with smaller buildings (Guet N'Dar and Sor). The correlation surfaces indicated that in areas of high homogeneity, for example road surfaces, the fractal model performed least well. Aggregate statistics for each image indicated that the statistical fit of the fractal model was high, with r^2 values ranging from 0.85 to 0.90, and minimum vales for D stabilizing at 2.0, as expected for smooth surfaces.

Neither the mean r^2 nor the mean D, however, could be used to differentiate between neighbourhoods. In addition, the method had to be expanded in order to investigate the concept of self-similarity. What was needed was a fractal investigation of city imagery at various resolutions. Rather than searching for such imagery, and attempting to compensate for differences in atmospheric conditions, sun angle, date, etc., it was decided to synthetically create imagery at a series of different resolutions, as follows.

Each image was decimated, such that the resolution of the new image was coarser than that of the original image, from which it was derived. Each decimated image covered the same ground area as the original image with fewer pixels. This decimation process was applied recursively, resulting in a series of six decimated images from each original full resolution image. The per pixel areal coverage of the decimated images was increased by factors of 2.25, 4, 9, 16, 64, and 256 respectively. These decimated images were produced using a process of bilinear interpolation, where the mean value of a centre pixel and its four surrounding pixels on the original image became the new value on the decimated image. This method of decimation was chosen over other methods, such as the `nearest neighbour' method, as it best approximated the way in which features are resolved on remotely sensed imagery. Each of these newly created images was then analyzed using the fractal program, creating a fractal and a correlation surface. Visual examination of the fractal surfaces revealed that the fractal process was capturing differences in the size of the `minimum building block' of the imagery. The fractal surfaces of the decimated images of the colonial sector, characterized by large buildings, began to resemble the fractal surfaces of the original, undecimated imagery of Guet N'Dar and Sor, characterized by smaller buildings.

Aggregate statistics of the fractal and correlation surfaces revealed that the conformity of the imagery to the fractal model was imperfect. Because of the bilinear interpolation used in the decimation of the imagery, one would expect a diminishing overall tonal range with each decimation and reduction of the mode and mean D values of the fractal surface derived from successive decimations. In all but the case of Guet N'Dar, however, the series of modal D values obtained from the set of decimated images of each neighbourhood first showed an increase in the modal D value with image decimation, then a decrease (Table 1). This pattern correlates to the pattern of the r^2 values, with the peak in fractal dimension corresponding to the best fit of the fractal model. Such statistical patterns may be explained in terms of data redundancy on the imagery. The images at full resolution contain clusters of pixels of similar value, representing, for example, rooftops, courtyards, or road surfaces. In the process of image decimation, this redundancy is reduced up to a point, as each pixel covers more ground area, but then buildings, alleys, and other features begin to merge together with further decimation, and data redundancy increases. A cluster of identifiable features on a full-resolution image becomes texture and then tone, through the process of decimation. Generally, the decimated image with the least data redundancy is the image with the most heterogeneity and the best fit of the fractal model, as given by the r^2 statistic. This assertion is supported by preliminary measurements of spatial

autocorrelation, as measured by Moran's I statistic (Kendel 1989: 972), another measure of texture.

For fractal surfaces at all resolutions, complete histogram information, not just summary statistics, was displayed visually. Figure 2 illustrates the process used in preparing this data, beginning with a hypothetical histogram of a fractal surface, which measures the percentage area of the fractal surface which represents a given fractal dimension of the original image. This histogram was classified into ranges of coverage, with darker values representing predominant fractal dimension values. To correspond with the final presentation of the information, this classified histogram was rotated ninety degrees, so that the y-axis represents the fractal dimension and the x-axis represents the percentage area. This representation was simplified by imagining that the percentage-area axis of the classified histogram was projecting out of the page and histogram bars were viewed from above, showing only the class in which a particular value falls. Thus a classed histogram was represented by a shaded ribbon, where shading intensity represents the area covered by a given D value.

These `histogram ribbons' may be compared by placing them side by side. Sets of fractal surfaces derived from images of one neighbourhood at different resolutions can be summarized in graphical terms by grouping the `histogram ribbons' of each neighbourhood to form a `histogram surface'. Figure 3 shows the `histogram ribbons' clustered together by neighbourhood, arranged such that the x-axis represents image resolution, with per pixel areal coverage increasing from left to right within each of the seven clusters. The y-axis represents the D value, and the percentage area of the image with a given D value is shown by intensity of shading. A modal trend line, based on modal D values shown in table 1, is plotted for each cluster. The range of D values, for each resolution, can be seen to vary with the mode. Neighbourhood image samples are provided for reference.

Results and Interpretation

The evidence from table 1 and figure 3 would indicate that with the possible exception of the Guet N'Dar sample, the imagery does not conform to the fractal model, over the ranges of resolution tested. Nevertheless, the above process holds promise as a way of describing and comparing the various neighbourhood morphologies. Figure 3 may be interpreted as displaying two different morphological characteristics. The first relates to the `minimum building block' of the image (related in real world terms to building size) and is indicated by the point along the areal resolution axis where the modal D is maximum. Larger `minimum building blocks' are indicated by a maximum modal D value further to the left along the resolution axis (Col1, Col2, Col3 and Pikine1) than in those images characterized by smaller building blocks (Guet N'Dar and Sor).

This interpretation must be analyzed carefully, however, as indicated by the Pikine1 and Pikine2 clusters. These two areas are similar in character, distinguished from each other only by density of habitation. In the case of the more sparsely settled Pikine2, the data redundancy is found mainly in open land, not in rooftops as in Pikine1. This indicates that the procedure may be used as a way of measuring

density of settlement, and indirectly, population density, but also indicates that results must be checked by visual interpretation.

The second characteristic is the degree to which the modal trend line is continuous. In the case of Sor and the Pikine samples, there would appear to be a break in the trend, which could perhaps be related to two different processes operating at different scales, for example, planning at the level of the household and planning at the city level. In the case of Sor this dichotomy is obvious, with an `organic' settlement pattern within a grid-based road network. Such a break in the trend could thus be considered as an indicator of `traditional' and `modern' forces operating on a settlement sometimes in opposition. Fractal analysis would seem to indicate, in tangible terms, the existence of such a socio-spatial dialectic .

Conclusions and Further Research

This selection of urban imagery conforms poorly to the fractal model. Nevertheless, in an analogous way to that proposed by researchers investigating natural processes (Goodchild and Mark 1987; Lam 1990) the fractal model holds promise as a way of describing and differentiating between various types of urban morphology.

Clearly this work should be considered exploratory in nature. As many questions are raised as are answered. For example, how universal is such a categorization? May it be applied to settlements other than Saint-Louis? What would happen if such techniques were applied to `traditional' settlements relatively free from `modern' influences? How much does settlement morphology reflect social history rather than current social `reality'? How well do spatial patterns conform to social patterns? Such issues are under perennial debate and will not be resolved here. Nevertheless, the techniques outlined above would appear to offer fresh insights to thorny and important issues regarding human settlement.

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Table 1. Summary Statistics of Fractal Surfaces

Neighbourhood	Per-Pixel Areal Coverage (Full resolution=1)							Statistic
	1	2.25	4	9	16	64	256	
Col1	2.31	2.34	2.41	2.43	2.45	2.41	2.33	Mean D
	2.30	2.39	2.49	2.49	2.48	2.40	2.30	Modal D
	0.87	0.90	0.92	0.93	0.93	0.92	0.91	r^2
Col2	2.32	2.34	2.40	2.42	2.45	2.42	2.34	Mean D
	2.34	2.42	2.44	2.44	2.44	2.42	2.37	Modal D
	0.85	0.86	0.88	0.90	0.92	0.93	0.92	r^2
Col3	2.34	2.37	2.42	2.43	2.44	2.39	2.34	Mean D
	2.41	2.44	2.46	2.45	2.44	2.38	2.31	Modal D
	0.90	0.90	0.92	0.93	0.92	0.92	0.92	r^2
Pikine1	2.34	2.38	2.43	2.45	2.46	2.44	2.32	Mean D
	2.39	2.43	2.46	2.44	2.46	2.42	2.29	Modal D
	0.90	0.91	0.93	0.93	0.93	0.93	0.91	r^2
Pikine2	2.30	2.34	2.40	2.42	2.46	2.47	2.35	Mean D
	2.38	2.37	2.44	2.45	2.47	2.48	2.35	Modal D
	0.89	0.90	0.92	0.94	0.94	0.94	0.92	r^2
Guet N'Dar	2.31	2.33	2.37	2.37	2.37	2.34	2.25	Mean D
	2.49	2.46	2.44	2.44	2.40	2.35	2.24	Modal D
	0.89	0.91	0.91	0.91	0.91	0.92	0.91	r^2
Sor	2.20	2.23	2.27	2.28	2.21	2.18	2.13	Mean D
	2.35	2.39	2.35	2.32	2.22	2.17	2.11	Modal D
	0.85	0.86	0.90	0.91	0.91	0.91	0.87	r^2

Figure 1. Euclidean Versus Fractal Dimension

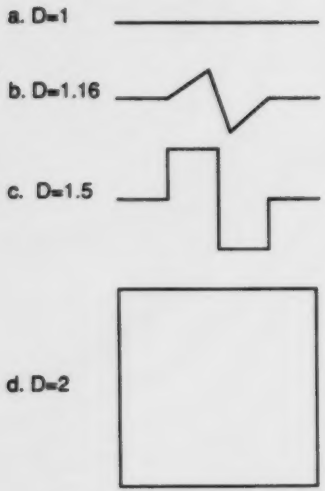


Figure 2. Method for Classification and Simplified Representation of Histogram Information Derived from Fractal Surface

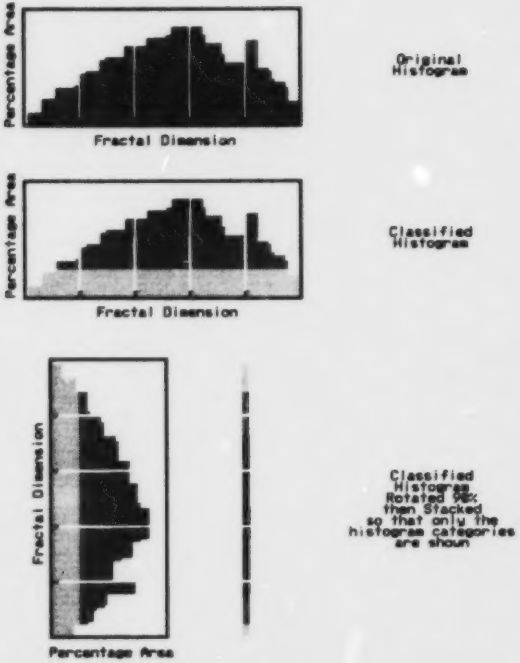
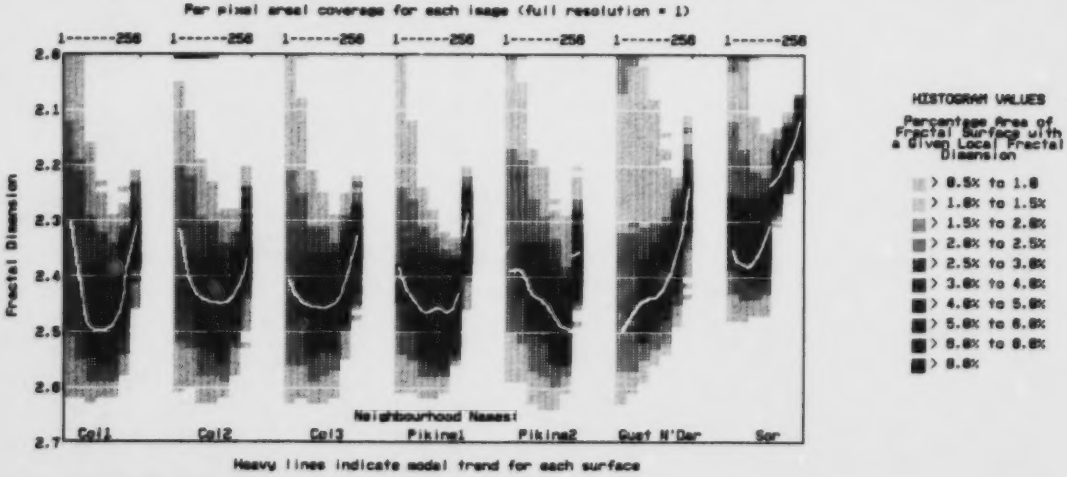
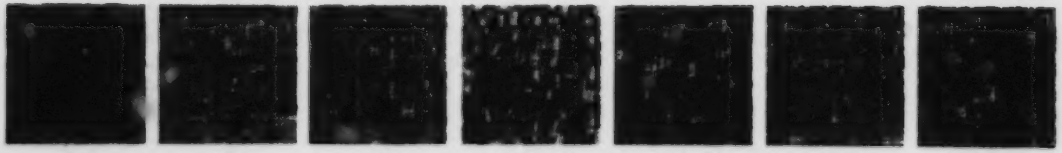


Figure 3. Histogram Surface Derived from Fractal Surfaces





G.I.S AS A TOOL TO RESOLVE NATURAL RESOURCE CONFLICTS

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ABSTRACT

In recent years there has been increasing interest in reviewing the development decision-making process at the municipal level. Various government agencies and private or crown corporations have continually encountered resistance from objecting interest groups when seeking to develop new sites or modify management techniques on existing properties.

The stakeholders involved often have highly varied interests and as such conflicts inevitably arise.

G.I.S. can be used as a facilitating tool because it has unique features that may aid in limiting or resolving some of these conflicts. It provides strong graphic capabilities as well as flexible and efficient spatial data management and manipulation. These features provide an opportunity for its use as an interactive tool to facilitate consultations and negotiations between the affected interest groups.

The use of G.I.S. will ensure decision-makers that significant efforts and a defensible methodology was employed to arrive at a mutually satisfactory final product.

LES SIG : UTILES POUR LE RÈGLEMENT DES DIFFÉRENDS SUR LES RESSOURCES NATURELLES

RÉSUMÉ

L'examen du processus décisionnnel en matière de développement à l'échelon municipal suscite, ces dernières années, un intérêt croissant. Les organismes gouvernementaux autant que les sociétés publiques ou privées qui désirent aménager de nouveaux sites ou modifier les méthodes de gestion des propriétés existantes se heurtent continuellement aux objections des groupes dissidents.

Souvent, les intérêts sont fort divergeants et donnent lieu à des différends.

Les systèmes d'information géographique (SIG) peuvent alors se révéler utiles grâce à leurs caractéristiques uniques susceptibles d'aider à résoudre les conflits, ou du moins à les atténuer. Outre leurs grandes capacités graphiques, les SIG permettent de gérer et de manipuler les données spatiales avec souplesse et efficacité. On peut ainsi s'en servir comme outil interactif pour faciliter les consultations et les négociations entre les groupes intéressés.

En recourant aux SIG, les décideurs seront assurés de déployer des efforts sérieux et d'employer une méthode défendable pour résoudre les différends à la satisfaction de tous les intervenants.

1.0 INTRODUCTION

The natural environment can present both technical and approval challenges to proponents of development. Government agencies (e.g., park planning groups, port and transportation authorities and works departments) and private or crown corporations (e.g., manufacturing plants, utilities and land developers) have often encountered objections, as they seek to develop new sites or modify management techniques on existing properties. The objectives often arise when some stakeholders have not been consulted during all stages of the development proposal.

The groups and individuals can include: federal, provincial and municipal government agencies, community associations, First Nations, individual citizens and special interest groups (e.g., naturalist club, angling and hunting organizations and agricultural associations).

All parties, or "stakeholders" involved, have different interests and objectives. Those differences are manifested as competition for the use of, and/or manipulation of natural resources for specific benefits. Inevitably, conflicts arise as a result of many factors, including:

- increased knowledge about, and documentation of the natural environment;
- a more interested, organized and involved public through community groups and special interest bodies;
- intensified competition for the remaining parcels of undeveloped land in and adjacent to built–up areas, and;
- more stringent rules (e.g., policies, guidelines, regulations etc.) at all levels of government, regarding the protection of natural environmental resources.

This paper discusses some issues that influence conflicts involving the natural environment and development, and describes the use of Geographical Information Systems (G.I.S.) as a tool to help resolve those conflicts.

2.0 FACTORS THAT LEAD TO NATURAL RESOURCE CONFLICTS

2.1 INCREASED DOCUMENTATION OF NATURAL RESOURCES

During the 1970's, various planning authorities began to undertake detailed environmental baseline studies and assessments of lands within their jurisdictions. At a municipal level for example, Environmentally Significant/Sensitive Areas (ESA) Studies described and mapped natural features considered to be important for one or a number of reasons. At a provincial level, a project to map and evaluate important wetlands south of the Canadian Shield, has been underway since the early 1980's. Another provincial government program sought to identify Areas of Natural and Scientific Interest (ANSIs) across Ontario. More specific technical programs sponsored by a mix of technical groups and government agencies have developed, and continue to develop, provincial atlases of breeding birds, reptiles, amphibians and mammals.

These different data have contributed to a better understanding of the importance or uniqueness of resources in a particular study area. As these databases become more advanced, they will continue to help answer questions that are often at the source of environmental conflicts: Just how important is a particular feature? Are there other examples nearby? What are the ecological implications associated with the removal of all or part of the feature?

A More Organized Public

Many groups and individuals are now more informed and aware about the environment and have taken an active interest in the integrity of the ecosystem. As a result, more of these groups are willing to come forward to help solve tough land use issues today. More people are now willing to invest time and money for natural environment issues that would, in the past, have received less attention.

More Competition for Less Land

In urban and near urban areas, developers have turned their attention to infilling and expansion into natural environment areas including woodlots, wetlands and valleylands. Developers are now willing to spend more money engineering difficult wooded or wetland sites within urban areas than to deal with the stringent rules that apply primarily to agricultural lands outside of urban areas. This situation has been more intense during periods

development growth like that faced in the mid to late 1980s. Periods of slows or no growth provide a time–out for the natural environment.

Environmental Rules are Getting Tougher

Most municipal governments, for example, currently undertaking an Official Plan Review or a Secondary Plan, are including more comprehensive evaluations of the existing natural environment. The physical and biological resources are being more critically examined and are having a more significant effect on planning exercises. The Oak Ridges Moraine Guidelines, the federal Fisheries Act, the newly released provincial Draft Wetland Policy Statement and a proliferation of municipal tree cutting bylaws and tree retention guidelines are just some of the regulatory initiatives to come forward lately. Some rules targeted towards the management of the same resources by different agencies, are themselves different. Overlapping agency mandates lead to increased confusion. As well, some rules are not clearly defined resulting in different interpretations by some stakeholders, thereby fueling conflicts.

3.0 G.I.S. AS A CONFLICT RESOLUTION TOOL

Traditionally, a report is provided to the regulatory agencies for review, as background to a development proposal. In these situations, the reviewers may be provided with adequate data and interpretations, but with limited presubmission consultation, they may possess a less complete understanding of how certain conclusions were reached. Review agencies and other stakeholders involved in the approval process inevitably have questions concerning some interpretations and conclusions made in the report. Poorly managed, these situations can lead to conflicts. In some cases, conflicts start well before any report is received.

G.I.S. as a tool, offers some advantages that could be used to limit the frequency and degree of these conflicts. It is a powerful tool for resource planning because it provides strong graphics and is flexible and efficient in the management and manipulation of spatial data. Besides using the G.I.S. for the interpretation and presentation of data, a significant opportunity exists to use it as an interactive tool to facilitate consultation and negotiations with affected parties or stakeholders. Stakeholders, including the regulatory agencies, can become involved by contributing to all phases of a project including data collection, interpretation and evaluation.

A four step approach is suggested to manage and focus consultation using G.I.S., thus limiting objections towards the end of the planning process. Those steps are:

1. Identification and Organization of Issues to be Resolved
2. Data Collection and Input Activities
3. Evaluation and Ranking Exercises
4. Mapping Exercises and Negotiation Sessions

The use of G.I.S. in each of these steps is summarized below.

1. Identification and Organization of Issues to be Resolved

The kinds of data to be gathered are identified by the scientists involved, from background information sources as well as from initial discussions with agencies and other interested and informed stakeholders. Those discussions will flag concerns and issues that will require subsequent investigation. Contributing to the issue indentification is a complete and accurate description of the development proposal. The details of what is proposed will influence the conflicts that could arise.

These issues are then grouped according to 1) ecological function, 2) environmental features, and, 3) engineering considerations. In the first instance, the grouping would include ground and surface water issues as they affect and support natural environment or biological features. Environmental features would include flora and fauna as well as areas of important biological activity (e.g. heronry for nesting colonial birds). Engineering considerations are those factors that would affect the ability to develop a property, for technical reasons. Examples are degree of slope and soil type.

2. Data Collection and Input Activities

Input from all identified stakeholders can be reviewed for contribution to the database. For example, observations of unusual wildlife reported by a local naturalist could be incorporated quickly and easily using G.I.S. This activity may also be particularly important when dealing with Aboriginal communities, whose members often have historical and personal knowledge of an area.

3. Evaluation and Ranking Exercises

The list of factors or interests identified by the stakeholders serves two purposes: 1) it acts as an educational tool by showing stakeholders that their interests are but a part of an integrated ecological planning exercise and, 2) it allows the stakeholders to assign some value or ranking to their specific interests. The ranking exercises can be conducted with each stakeholder individually, or collectively as a group. Regardless, the exercise will help to generate an understanding of the values attributed to the biophysical resources by others. The mapping exercise described in point 4, discusses how the ranking allows stakeholders to "visualize" the implications of that exercise.

Table 1 provides a hypothetical example of how some stakeholders ranked a list of factors developed for a particular area. Their assignment of a value to each, is related to their individual knowledge of the study area as well as their mandate or interest in the management of natural resources. Table 1 also provides each stakeholder with an indication of the relative importance attached to the resources by others.

The rankings range in value from 1 to 4 with 4 representing the most sensitive areas or those areas least desirable for development. The rankings provide a relative evaluation of areal features within each map factor. The weightings are values which total 100 and are assigned to each map. These values establish the relative importance of each map.

Another benefit of this cooperative mapping exercise is that the generated maps may be brought back to the stakeholders for verification. They are also useful to scientists in the field, for the verification of boundaries and data points.

4. Mapping Exercises and Negotiation Sessions

G.I.S. is capable of translating the variously ranked lists of issues into natural resource mapping. These baseline maps can be created using a myriad of colours to effectively depict contrasts and degrees of sustainability or development capability of an area's resources. The maps which are produced using rankings provided by different stakeholders will obviously differ in appearance. One feature of G.I.S. which may assist in minimizing these differences is the ability to query the rankings assigned to certain features by the different stakeholders. Map 1 depicts how the system would interactively query the features by simply moving the cursor over the map.

Since different stakeholders are not interested in the same factors, the system can also be used to simultaneously display different mapped features (Map 2). This approach allows the stakeholders to view several features at the same time, and compare their spatial relationships. While the stakeholders may not be looking for areas of agreement, the maps do, by their nature enable stakeholders to see common areas of interest.

In the past, these exercises were completed through the use of tables and mathematical manipulations. Visual presentations have generally tended to be more effective since they relate in a spatial context to "real" landmarks (e.g., homes, parks, etc.). This results in the stakeholders being more willing to take ownership of the mapped factors.

A stakeholder's values and objectives may be represented by mapping the implications of their rankings on the development capability of an area. In this way, the maps serve as a very graphic starting point for trade–off or negotiating sessions. This approach facilitates a proactive rather than a reactive negotiating process, allowing stakeholders to focus more on interests and less on posturing.

G.I.S. provides certain other features that are of benefit during these trade–off or negotiating sessions. It allows for a focused discussion and explanation of the various positions. This process can spark more creative, win–win solutions to resource problems by helping to find innovative ways to mutually satisfy the needs of many stakeholders. For example, this approach could result in the identification of ways to relocate or reallocate resources, to meet interests of certain parties.

G.I.S. can also quickly calculate the aerial extents of different resources as input to a determination of the lands considered to be more appropriate for certain kinds of development (Figure 1). Private proponents in the land development sector find this technique of particular interest when attempting to calculate the financial soundness of investment decisions. Area cross–tabulations can be used to determine how much area will be gained or lost between two given scenarios which have resulted from different weighting and ranking schemes (Figure 2). It can thus be of assistance in helping stakeholders understand the pros and cons associated with the designation of certain features.

4.0 CONCLUSIONS

More traditional approaches to resolving conflicts involving natural resources have resulted in confrontational encounters, often unresolved without environmental and municipal hearings. Some of these problems have resulted from a lack of communication between the various stakeholders and a lack of understanding on the part of the stakeholders, of the role of certain scientific elements of a project. G.I.S. can be used as a powerful visual aide to enable stakeholders to view the environmental database constructed, as well as to follow, step–by–step through the manipulation and evaluation of data supporting a particular conclusion.

The use of the G.I.S. can help to minimize and control some conflicts. It can also:

- demonstrate to hearing panels and decision makers that significant efforts were expended to enhance and optimize consultation;
- pinpoint areas of conflict allowing energies within or outside of hearings to be focused on the resolution of significant differences, without distraction;
- contribute to the quality, accuracy and defensibility of the final product, and;
- optimize the sustainability of natural resources, while permitting some degree of development and some degree of mutual satisfaction of stakeholder objectives.

Indexing Overlay Input File		
new mapid & title: MNR MNR Desirability Map		
no of input Maps: 4 Input Maps (Id Max Color) biology 4 heron 1 geology 6 slope 4		
WEIGHT MAP ID TITLE		
60.000 biology: BIOLOGICAL FACTORS		
	0:	1
plants	1:	2
ansi	2:	4
wetland	3:	4
streams	4:	4
10.000 heron: HERONRY LOCATION MAP		
	0:	1
deer	1:	4
15.000 geology: GEOLOGY MAP		
	0:	1
till	1:	2
sand	2:	2
gravel	3:	2
kame	4:	2
wetland	5:	4
water	6:	4
15.000 slope: SLOPE ANALYSIS MAP		
	0:	1
steep	1:	4
moderat	2:	4
gentle	3:	2
flat	4:	2

TABLE 1: Hypothetical Example of Weightings And Ranking Assigned To Relevant Factors By A Stakeholder

HYPOEXAM.wk3 30-Jan-92 ADMIN/CL

GEOLOGY

Legend.

- Glacial Till.
- Beach Sand (H.W.T.).
- Beach Sand & Gravel (L.W.T.).
- Kame.
- Wetlands (Recharge).
- Watercourses & Seepage Areas

1 km

Query Data

-79 43' 25"W (-79.7237)	44 21' 1" N (44.35)
601727 m 13080 univ.	4911362 m 6976 univ.
Grid Reference	17TPV 172711362

cagcol	(Conservation Authority)	3
coungcol	(Town Council)	3
mnrgcol	(M.N.R.)	2
moegcol	(M.O.E.)	2
natgcol	(Naturalists)	4

MAP 1 : Querying Rankings of a Specific Factor by Different Stake Holders

MAP 2 : Simultaneous Spatial Visualization of Several Factors

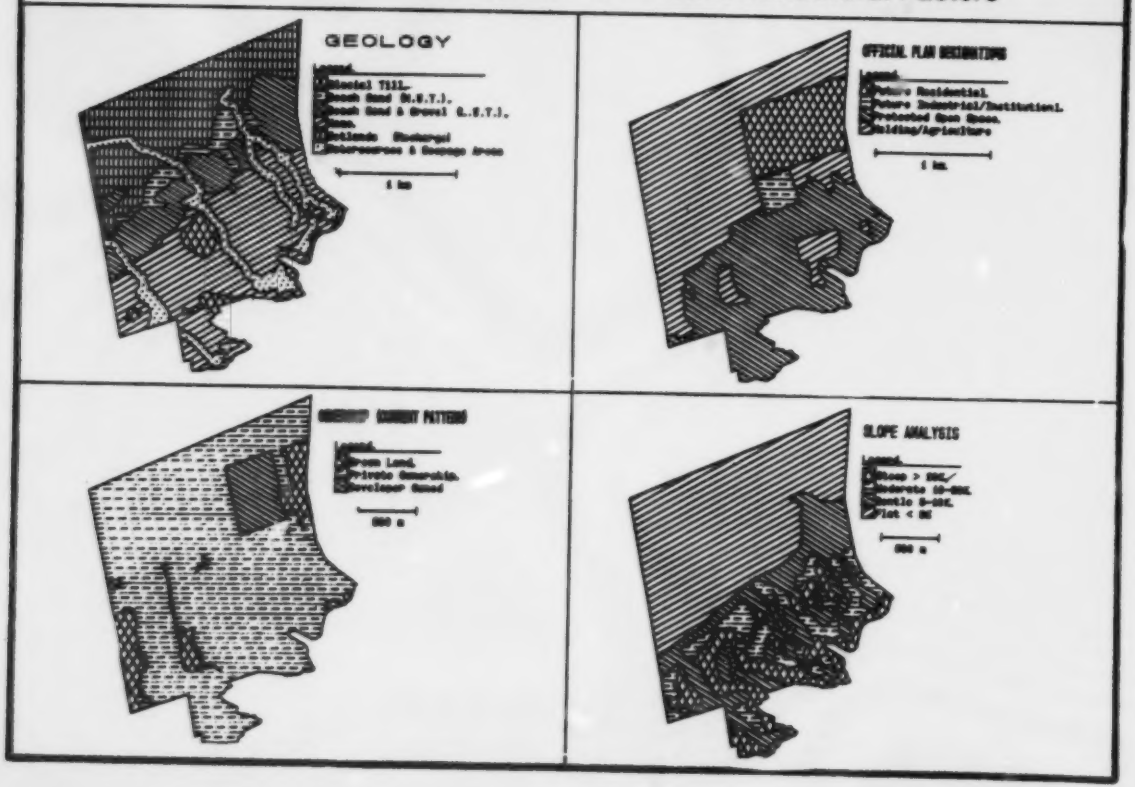

FIGURE 1: CALCULATION OF AREA BY CLASS

SINGLE MAP ANALYSIS

Map : conflict – Resolved Development Plan

Window : pa – Project Area Window

Class Legend	Area % (%)	Cumm % Area	Area (km²) (km²)
1 High Constraint	0.36	0.36	0.01423
2 Moderate Constraint	69.77	70.13	2.77383
3 Low Constraint	29.86	99.99	1.18706
4 No Constraint	0.01	100	0.00045
Total of 4 classes	100		3.97557

FIGURE 2: CALCULATION OF CHANGES IN AREA BY CLASS FOR DIFFERENT SCENARIOS

AREA CROSS TABULATION

Row : dvlpl – Development Zones
Col : conflict – Resolved Development Plan

Window : pa – Project Area Window

Contingency Coefficient	0.6271
Tschuprow's T	0.5144
Cramer's V	0.5666

Area (km sq)
Total %
Row %
Col %

	high	moderate	low	none	Total
low	0.01423	1.38804	0.06896	0	1.46723
	0.36	34.79	1.76	0	36.91
	0.97	94.26	4.77	0	
	100	49.86	5.89	0	
moderate	0	1.39079	0.27589	0	1.66668
	0	34.98	6.94	0	41.92
	0	83.45	16.55	0	
	0	50.14	23.24	0	
high	0	0	0.84121	0.00045	0.84166
	0	0	21.16	0.01	21.17
	0	0	99.95	0.05	
	0	0	70.87	100	
Total	0.01423	2.77383	1.18706	0.00045	3.97557
	0.36	69.77	29.86	0.01	

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MOVING TOWARDS GIS: DEVELOPING NOVA SCOTIA'S HIGHWAY REFERENCING SYSTEM

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ABSTRACT

In the spring of 1991, the Nova Scotia Department of Transportation and Communications launched a study aimed at developing a highway location referencing system for use by all divisions within the Department. The objective of the work was to develop a system which could be used to bring together the disparate referencing systems in use by various divisions within the Department at that time. In the near term, such a system was seen as being the key to developing an integrated transportation information management system. In the longer term, the work was seen as setting the stage for moving towards the implementation of a geographic information system within the Department.

This paper describes the development of the highway location referencing system for the Department and focuses on the practical issues related to carrying out such work in the context of a longer term goal of ensuring GIS compatibility. The topics covered include: a review of highway location referencing systems; a review of Canadian and U.S. GIS experiences; practical design considerations, including dynamic segmentation; description of the proposed system; implementation issues; alternative computing platforms and scenarios; application of GIS and GPS; and, field operations and communication issues.

Vers le SIG : le système de localisation routière de la Nouvelle-Écosse

RÉSUMÉ

Au printemps de 1991, le ministère des Transports et des Communications de la Nouvelle-Écosse a entrepris une étude en vue de mettre au point un système de localisation routière devant servir à toutes les divisions du ministère. On voulait un système qui permette de fusionner les différents systèmes alors en usage dans diverses divisions. Dans l'immédiat, ce système devait servir de base pour la mise au point d'un système de gestion intégrée de l'information sur les transports. À plus long terme, il doit servir de cadre pour l'établissement progressif d'un système d'information géographique au ministère.

Dans cette présentation, il est question de la mise au point du système de localisation routière du ministère et plus particulièrement des aspects pratiques qu'un tel projet comporte à l'égard de la compatibilité avec le SIG qu'on veut établir à long terme. On examine notamment les points suivants : les systèmes de localisation routière existants; les SIG du Canada et des États-Unis; les considérations pratiques en matière de conception, notamment concernant la segmentation dynamique; la description du système projeté; la mise en oeuvre; d'autres plate-formes et hypothèses de travail équivalentes; les applications du SIG et du SPG ainsi que des aspects concernant le travail sur le terrain et les communications.

1.1 Introduction

In 1990, UMA Engineering Ltd. was retained by the Nova Scotia Department of Transportation and Communications (NSDOTC) to conduct a study to **"Develop a Highway Location Reference System and Method(s)"**. The project was undertaken as part of the Evaluation Component within the Canada/Nova Scotia Highway Improvement Agreement.

1.2 Definitions

For the purposes of this study, the following definitions apply:

> **Highway Location Reference System** - *the total set of procedures for determining and retaining a record of specific points along a highway. The system includes the location reference method(s) together with the procedures for storing, maintaining, and retrieving location information about points and segments on the highways;* and
>
> **Highway Location Reference Method** - *the technique used to identify a specific point (location) or segment of highway, either in the field or in the office.*

1.3 Study Objectives

The general study objective was to develop a highway reference system and method(s) for use by all Department personnel, with the following more specific objectives:

1. To develop a highway location reference system for use by all divisions of the Department, including guidelines on how each would implement the reference system so as to result in a consistent and compatible application across all highway related information and collection and processing activities.

2. To develop a highway location reference method(s) for use by all divisions and field staff in identifying the location of each data item or activity. This must emphasize those methods that provide simple and fast procedures for identifying an individual location, and provide for uniformity in application of procedures through which various highway related data are referenced. Given future mapping implementation, the location reference method must also be capable of being easily geo-referenced.

In addition, given that the Highway Location Reference System and Location Reference Method(s) will be applied to the entire provincial highway system, any such method will have to be able to include both high volume multilane arterial highways and lower volume local roads.

The development of a Highway Location Reference System and Method(s) is of critical importance to NSDOTC, given that it will provide the necessary technical and conceptual methodologies to integrate all existing data within the Department (and data from external sources). The importance of the Project is even more critical considering its requirement to be able to encompass other on-going initiatives (e.g., the "Environmental Data Base Study: Highway Construction", and the "Maintenance Management System: Preliminary Analysis") and future requirements for the development of a Pavement Management System and Geographic Information System.

It will also serve as a mechanism by which external users of transportation referenced data can access important attribute information to aid data management and improve decision making.

These initiatives are a fundamental component of a longer term strategy to develop a fully integrated "Transportation Information System". The eventual implementation of such a system and its subsequent success will depend heavily on the development of an effective Highway Location Reference System and Method(s). Therefore, the project is not only of considerable importance to the Department in the short term, but will also be critical to the successful development of future initiatives.

2.1 Overview of Systems and Methods

In general terms, a Highway Location Reference System is a set of office and field procedures that includes a Highway Location Reference Method. The System can be seen as the set of procedures that relate all locations to each other, and includes techniques for storing, maintaining and retrieving locational information. The Method is a way to identify a specific location with respect to a known point.

The objectives of any highway location reference method are far reaching, however a number of the most important objectives can be outlined as follows. The chosen method must be able to:

- provide a means for designating and recording the geographic positions of specific locations on a highway and for using the designations as a key to stored information about the locations. Using the designations as a key permits users of the method to use or modify stored information and subsequently to find a location in the field. Thus, the identification of a location can be made in the field at the time of data collection or later in the office.

- pay due regard to the potential users and to the techniques that would have to be employed in using the method.

- provide an orientation toward use in the field. It therefore, must be simple and fast, because it is used by personnel at various levels of technical competence.

- provide a uniformity in the application of procedures through which various highway-related data observations are located, identified and recorded, to facilitate the correlation of all points. It should not depend on the independent viewpoints of various organizations making the observations.

2.2 Context

The concept of a Location Reference System is not new. Early origins can be traced back to the Roman Empire (although they may have had earlier origins in Asia), where road milestones were used to inform travellers of distances from an origin or destination, usually a city. In Britain, roads built by the Romans exhibited these characteristics, although official distance markers didn't appear in England until the eighteenth century. Some of the earliest examples of the use of milestones in the United States began to appear in the late 1700s, with the earliest probably being the Boston Post Road. The use of milestones (now termed mileposts) became much more widespread in the early 1920s, but it was the increasing availability of computer technology which really influenced the widespread implementation of location reference system methodologies.

A major impetus to the development of location reference systems in the 1960s was the 1966 United States Highway Act, which helped to promote the development of safety standards, and required procedures for accurately identifying accident locations. Federal aid in the form of safety and planning funds were increasingly used to help various jurisdictions adopt procedures for the identification and surveillance of high accident locations. The implementation of location reference systems was also aided by a prevailing attitude that considered them as a convenience to the travelling public, a view which receives far less consideration today.

Early systems were also used to assist travellers to orient their position on a public way to an intended destination, or some other location of importance. It is only in recent years that highway location reference systems have been used to help improve highway agency functions such as planning, safety and maintenance.

There appear to be numerous, widely different, location reference methods in use today throughout North America, but it can be argued that there is not a great deal of **fundamental** difference between them. A number of common elements can be identified: (i) identification of a known point; (ii) a measurement from a known point; and (iii) a direction of measurement. The presence of these three defining elements allows the computation of a true milepoint for a given location. Therefore, given the presence of these common elements, it is also possible to derive a milepoint identification for a location using any one of several location reference methods.

2.3 Referencing System Developments

It is evident that for highway information purposes, locational reference schemes most commonly used to date have a linear orientation, rather than a coordinate approach. The reference metric is usually some distance or length along the highway. While many

specific methodologies exist to implement such linear referencing systems, the literature suggests that these can generally be classified into three basic schemes:

1: Road name and reference
2: Control Section
3: Link (chain) and node

Road Name and Reference Point:
Generally, such systems consists of two primary elements: a road naming convention and a series of reference points. Most commonly, the road naming convention used is a unique route number. Reference points may in some cases be referred to as "milepoints" and indicate cumulative mileage along the facility from a defined starting point. Difficulties in maintaining actual mileages in the face of road relocations have, however, led to a more general use of physical reference points along the road as "anchors" for such systems. Offset mileages from reference points are used to indicate specific object locations (ie. signs, small structures etc.).

Control Section Locational Reference:
Control section reference schemes are usually established in the context of specific applications - pavement management for instance. In such schemes, the emphasis is generally on establishing a length of highway so that the types of data to be associated with that section are homogeneous in nature. Control sections are usually anchored at either end with reference to a specific milepoint or feature (ie. intersection). They may also be broken down into sub-sections for particular purposes (ie. rating sections in a pavement management system). The control section approach has also been used to provide a constant referencing system framework for an agency (ie. as a type of naming convention) with differing subdivisions (segmentations) used within it for recording different attributes.

Link (chain) and Node Locational Reference:
Link and node referencing schemes attempt to model the topology (spatial relationships) of the road network. In this case, intersections, changes in highway direction or other critical physical features are defined as nodes and assigned a unique node number. Each node is connected to at least one other node, by a section of road called a link. Thus, each link can be identified as a unique part of the road network by its terminal node reference numbers. In these systems, links are often subdivided into individual segments. Locations within the segments are identified by offset distances - usually from nodes or from the beginning of a segment. These systems have an advantage over the others in that they provide access to the actual physical network topology and can also provide the coordinate geometry.

While each of these systems is different in concept, they are really quite similar in application. All use a distance measurement from a known point to the object of interest, a direction of measurement and a description of the known point. These characteristics are fundamental, regardless of whether the true physical location is calculated in the field, done manually in the office or performed by a computer (National Research Council,

1974). Within the context of these locational referencing systems, data elements can usually be cross referenced by using distance offsets from common known locations.

Referencing systems are used to describe the physical location of any given point on the highway system. However, the reason for describing a particular point is usually in order to say something about a physical feature which begins, ends, or exists at that point. The description of the physical feature is termed an attribute. Thus, a data base actually contains two critical elements which must be coordinated in order to enable true integration of the data sets: (i) locational referencing information, and (ii) attribute information.

Attribute information has often been a controlling factor in determining how a locational referencing system has been structured or segmented, and thus, how it may be analyzed. Traffic engineers, for instance, might segment the network into strata of similar traffic volumes. Designers might use the number of lanes as a key for segmentation. Pavement engineers on the other hand, may wish to divide the network into segments with homogeneous surface characteristics.

3.1 Experience

In order to assess the experience of other Canadian (various U.S agencies were contacted as part of the project although the specifics are not reported here) provincial agencies with the development of referencing systems, representatives of these agencies were contacted by telephone and interviewed in an informal survey.

As would probably be expected, there is commonality among the practices of Canadian provincial transportation agencies with respect to referencing systems. A number of key observations can be drawn together from this survey.

1: All agencies recognize the desirability of using a common referencing system throughout their operations in order to allow for data base integration and more effective analysis and decision support.

2: Agencies also generally recognize the need for differential approaches to system segmentation for different purposes, but attempt to implement such approaches within one uniform base framework.

3: Prime responsibility for referencing systems maintenance and continuing development is generally the function of the planning division in consultation with the other users of the system within the department.

4: The fact that a common referencing system exists has not necessarily led to an integration of all data bases and/or an integrated analysis approach.

5: Basic referencing system catalogues are usually map/document based.

6: Data storage/analysis is most often mainframe based, however many agencies have also moved key analysis functions to the personal computer level for individual divisional activities.

7: Implementation of a standard referencing system does not overcome the data integration problem generated by differential segmentation approaches used by different divisions. In many cases, integration of data in such instances is accomplished manually.

8: Only Saskatchewan has successfully implemented a dynamic segmentation approach within its system. This is also the only province to have successfully implemented a GIS to date.

9: All provinces indicated some level of interest and/or activity in GIS.

10: Three provinces, (N.B., Alberta and British Columbia), have new internal committees in place to examine their current referencing system practices.

3.2 NSDOTC Experience

In order to assess the experience of NSDOTC with the development of referencing systems, the major divisions of the Department were interviewed, these included: Planning, Traffic, Engineering, Inspection, Maintenance, Right-of-Claims, Computer Services, Regional offices (Bedford, Middleton and New Minas), Materials Laboratory, Outfits, Financial Services, Highway Safety and Field Programs, and the Registry of Motor Vehicles. The Police Forces and Emergency Measures Organization were also contacted for further input to the study.

The results of the survey process reveal that there is a considerable amount of disparity in the use of highway location referencing systems and methods within NSDOTC. A number of important observations can be made concerning the general needs and requirements for the proposed referencing system. These parallel a number of the earlier general points made in reference to experiences elsewhere in Canada (and in the United States). As a result of this process three key issues were identified that serve to underlie the technical direction for the project:

- DISPARATE REFERENCING SYSTEMS often do exist within highway agencies. A prime goal is to develop a common key to help link these systems and thus allow data integration.

- DYNAMIC SEGMENTATION techniques offer an efficient and effective way to allow for the existence of differentiated network segmentations for individual applications. Any referencing system must allow for implementation of such techniques in the future.

- GEOGRAPHIC INFORMATION SYSTEMS are a new and innovative technology that can facilitate data base integration and greatly enhance the data capture, analysis and reporting capabilities of a transportation agency. Any referencing system must allow for the potential migration of data bases to GIS in the future.

The three basic components of the proposed LINK referencing system include:

1. *The Methodology* - How the system is to be built and maintained.
2. *A Control Reference Base* (CRB) - The base highway system breakdown.
3. A series of *Component Referencing Overlays* (CRO) - The different segmentation and keypoint maps used by different divisions of NSDOTC.

The methodology provides the basis for building, operating and maintaining both the CRB and the component referencing overlays. It is documented in both a procedures manual and an electronic data entry system. A link-node system, similar to that used in Ontario's Linear Highway Referencing System (LHRS), is used for segmenting the basic highway network. Such systems are highly adaptable to GIS and allow for the type of differential segmentation and multiple overlay approach.

The Control Reference Base (CRB) provides the basic link-node structure which is common to all of the overlays. It is the basic skeleton upon which the meat of the referencing system hangs. It can be documented in a catalogue, (probably a combination of document/maps), and can be in both physical and electronic form. A prototype database building tool has been developed as part of this system to allow for the initial implementation and subsequent maintenance of the CRB portion of the LINK/PAC system in electronic form on micro-computer.

The Component Referencing Overlays (CRO) represent the differential segmentation approaches used by the various divisions within NSDOTC. These are developed by individual divisions within the Department in the course of implementing the referencing system. It can also be documented in a catalogue, in both physical and electronic form. The prototype database building tool mentioned above also has the capability of building and maintaining the CRO portion of the LINK/PAC system in electronic form. In some cases, the construction of these CRO's requires modification of current field location recording procedures.

The LINK referencing system recommended for use is similar to a mile post referencing system. One of its primary purposes is to allow the conversion of a natural type of user reference to an object or event on the highway into a formal computer reference number. Its basic structure is simple:

- Each highway is assigned a continuous and unique set of five digit reference numbers used only for that road.

- The numbers are assigned in ascending order to well recognized features such as intersections, river crossings, etc. These points are termed base points, and effectively divide the highway into a series of sections. A specific section is identified by using the number of the base point which identifies the beginning of the section.

- Less important features (or components) are identified by an additional three digit number representing the offset from a specific base point - measured in tenths of a kilometre. The base point has a zero offset.

A single LINEAR REFERENCE SYSTEM (LRS) number can thus be used to identify three attributes:

1: A unique identifier for the roadway: (5 digits + 3 zeros: or just 5 digits)
2: A unique identification for a key event (base point) on that roadway: (5 digits + 3 zeros: or just 5 digits)
3: The distance in tenths of a kilometre from the last base point: (5 digits + 3 digits for the offset distance)

4.1 System Elements

The referencing system is intended to provide the necessary locational reference base for all aspects of the Department's work, including such areas as traffic, pavement management, maintenance management, construction, engineering etc.. It is also intended to provide sufficient flexibility that new components and/or functions can be added to it at any time in the future. A basic set of principles underlies the design of the system.

1: The system includes all provincial highways.
2: The referencing is continuous throughout the length of the highways and thus includes links which provide continuity to the system, but which are not necessarily under the Department's direct charge.
3: Some archiving capability is desirable in order to provide historical tracking of changes in the network.
4: Jurisdictional boundaries are identified as part of the system. These should include County, Municipal, NSDOTC District boundaries and others as required.
5: The system provides the capability of documenting references to multiple features including intersections, railway crossings, structures and others.
6: The system allows for the development of distinct referencing system breakdowns for different divisions within the Department, but provides the means for integrating the data from these.
7: The system is adaptable to use with dynamic segmentation techniques and integration with a Geographic Information System in the future.
8: The system is accessible and easy to use and maintain.

The CRB component of the "link" referencing system is modelled after Ontario's Linear Highway Referencing System and incorporates the following basic design concepts:

1: Every provincial highway is divided into consecutive sections which have unique reference numbers (Linear Reference Numbers: LRS) assigned to them in ascending order.
2: The starting point of any section is defined as being the point at which two highways intersect. Where this would result in sections exceeding 20 km in length, the sections are divided at a particular visible feature (ie. a bridge, culvert etc..).
3: The numbering system should be independent of any current numbering system or naming convention and should leave gaps in its structure to allow for changes, additions or other modifications to the network in the future. It is recommended that the numbering scheme start with 10010 for the first section of the lowest numbered highway and simply increase the LRS number for each consecutive section by 10 until the end of the highway is reached.
4: After the end of a highway is reached, a significant gap (at least 100) should be left for extensions and other changes to the highway.

The CRB therefore provides the basic division of the highway system into the elements which are common to all of the individual overlays.

Component Referencing Overlays are used to provide supplementary documentation of features and keypoints related to individual user groups. All features and keypoints used in the overlays are referenced to an offset distance measured from the start (or base point) of the relevant section. Features may be included in an overlay for their own sake, or may be included to provide a logical break where an attribute of particular interest changes value. Generally, all major, visible, physical features which are part of the network are recorded in this fashion. In addition, jurisdictional boundary lines must be included as well. Such boundaries include not only the County breakdowns, but also NSDOTC District boundaries and others as required. The CRO capability is also used to build overlays related to two special features of a highway network: ramps and off-highway references.

Each CRO is stored as an individual sequential file, ordered by LRS number and offset distance within the LRS section. Multiple features may appear at a single point on a highway - for instance, municipal boundaries coinciding with intersections and/or a change of NSDOTC district boundaries. Feature points are located by an offset distance measured to the 0.01 km accuracy from the base point of the section.

Where highways are physically separate by direction, one way sections are given a different LRS number and are all cross referenced by a code and a duplicate LRS number to the corresponding facility in the opposite direction. Interchange ramps are tracked by assigning identification sub-references. In addition, provision is made for tying these sub-references to physical points (i.e. lamp-poles) where necessary. In complex instances, a physical diagram is held on file which notes the breakdown of sub-reference numbers for the ramps etc.

4.2 Updating and Modifying the Files

The constant updating of both the CRB and CRO files is essential to the effective use of the referencing system. The procedures for each file are separate but related operations. Coordination and quality control of all changes must be accomplished through some centralized group, however it is recognized that the process of revision will be initiated by a number of different sources. Procedures related to the maintenance of the CRB files relate to nine distinct types of modification: opening of a new highway; opening of a bypass; extension of a highway; realignment of a highway; closing of a highway; transferring a highway; distance correction; description of changes; and merge/split section (the relevant procedures are documented in a manual which accompanies the reference system).

5.1 Implementation

Given that the implementation of the referencing system will be carried out in the context of a broader plan of action, which includes the development and exploitation of integrated databases, the proposed implementation will require a corporate approach to the sharing of data. The ability to share data among various users in the Department requires the adoption of common standards and specifications, but more importantly requires cooperation. Thus, the successful implementation of the referencing system and development of integrated databases (working toward GIS in the long term) depends on the ability to share data to satisfy applications, which implies a high degree of willingness to coordinate, and a commitment at both political and managerial levels.

Ultimately the success of the proposed referencing system will depend on the people who actually implement it. It is their enthusiasm and commitment that will see the project through the inevitable stumbles and set-backs. Management of the process will be absolutely critical. The implementation plan will therefore define the group or groups within the Department who will be responsible for the implementation and operation of the referencing system.

The successful implementation of the referencing system will also be carried out in the context of a broader plan of action which includes the following elements: development of the Core Reference Base; development of the Component Referencing Overlays; implementation of the necessary administrative systems for continuing maintenance of the referencing system; a data and functional modelling system; design of database structure; prototyping; development of integrated database; development of integrated transportation information system.

The overall implementation of the referencing system will also necessitate the following: establish four level committee structure; establish reference system development policy, information handling policy, standards policy, highway location system showcase; implementation of an education and training program, technical implementation plan, data

base modelling study, data base structure study; and an integrated database/GIS framework study.

5.2 GIS-T & Applications

Nyerges defines a Geographic Information System as:

> "...a system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth." (Nyerges, 1990)

Transportation networks are primarily geographically based. The systems themselves consist of nodes, links and objects or entities which are distributed in a three dimensional space. Objects (bridges, signals, etc) or occurrences (pavement deterioration, accidents, etc) happen within the system - sometimes at a point, sometimes along a section of road or sometimes within an area. Basic locational referencing systems as already described are fundamental to the management of transportation systems because of the spatial orientation of those systems.

Although the concept of integrating transportation information through a common locational referencing system link is not new, recent advances in GIS technology - at both the hardware and software levels - have opened up a whole new horizon of possibilities for transportation system agencies. Abkowitz notes:

> "Because the field of transportation is inherently geographic, GIS poses a technology with considerable potential for achieving dramatic gains in efficiency and productivity for a multitude of traditional transportation applications, as well as creating the opportunity to develop new applications that heretofore were considered infeasible." (Abkowitz et al, 1990)

A GIS contains two types of information:

> 1: Spatial information about where things are in the system being described (usually in 2 or 3 dimensions as required).
>
> 2: Information about the characteristics of the objects, (elements, entities etc), which make up the system.

The spatial information allows objects to be described as a point (ie. location of an accident), a line (ie. a section of a highway), or a polygon (ie. the boundaries of a town). Strict mathematical relations define the spatial positions of every object in the system in terms of geocoordinates and topology (connectedness, shape).

The information about the characteristics of the objects is termed "attributes". These attributes are the kinds of things normally described in a traditional data base. For instance, the different attributes of a section of highway might include the number of

lanes, traffic volumes, pavement conditions and rehabilitation history, among other things.

What makes a GIS different from a traditional data base is the fact that the attribute data are associated with objects whose position on the face of the earth are known. When these data are integrated within the GIS, based on a common locational referencing system, diverse sets of data which could not be integrated previously, can be manipulated, combined and examined through a simple, straightforward - and generally interactive - process. Text reports can be generated, as can graphical outputs and displays. Analytical models can be developed within the structures, or linked to the GIS to exploit its data analysis features in their own analyses. The ability to examine the results of analyses, or even to build those analyses interactively within a spatial display context - **for a system that is spatially oriented** -is a very powerful tool indeed.

Potential GIS applications can be generally grouped into the following broad categories: geocoding; index mapping; automated mapping; georeferenced models; linear referencing; geopositional framework management; property management; facilities management; geographical analysis; and research. A GIS Pilot/Demonstration is currently being undertaken to examine some of these applications together with the implementation of the referencing system in a selected region of Nova Scotia.

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EXPERIMENTS IN COMBINING GEOLOGY MAPS WITH TERRAIN RELIEF DATA

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ABSTRACT

The topographical relief of a region is of direct interest to the field geologist. The manner in which structural features such as folds, faults, foliations, lineations, and joints are expressed via topographic relief, has bearing on the way a geologist will map an area or interpret an existing geology map. The Non-Renewable Resource Group of the Canada Centre of Remote Sensing and the Geoscience Information Division of the Geological Survey of Canada have collaborated on producing experimental geology maps which combine topographic relief with existing 1:250,000 scale geology maps using a combination of Image Analysis and Computer-Assisted Cartographic techniques. Two sources of relief information are examined; 1) Airborne Synthetic Aperture Radar (SAR) Data, and 2) Digital Terrain Elevation Data (DTED). The algorithm used to combine the two data types is based upon an Intensity-Hue-Saturation (IHS) colour transform. Final products are optimized for both hardcopy and digital output products. Various processing steps involved in producing the maps along with recommendations of future enhancements are discussed.

RÉUNION EXPÉRIMENTALE DES CARTES GÉOLOGIQUES ET DONNÉES DERELIEF

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RÉSUMÉ

Le relief topographique d'une région donnée intéresse immédiatement le géologue sur le terrain. La façon dont les éléments du relief (plis, failles, foliations, linéations et diaclases s'expriment à travers le relief, se répercutent sur la façon dont le géologue dressera sa carte ou interprétera une carte. Le Groupe des ressources non renouvelables du Centre canadien de télédétection et de la Division de l'information géoscientifique de la Commission géologique du Canada ont collaboré à la production de cartes géologiques expérimentales réunissant les éléments du relief topographique et les cartes géologiques à l'échelle de 1:250 000 à l'aide de techniques d'analyse d'images et de cartographie informatisée. Le document porte sur deux formes de données sur le relief : celles que procure le radar aérien à ouverture synthétique et les données d'élévation digitalisées. L'algorithme servant à combiner ces données repose sur une impression transformée en couleurs faite à l'aide d'un modèle intensité-tonalité-saturation. Les produits définitifs sont optimisés à des fins d'impression et de production sur support informatique. Diverses méthodes de traitement sont employées pour produire les cartes. Le document offre des recommandations visant l'amélioration future du procédé.

DYNAMIC SPATIAL DATA STRUCTURES - THE VORONOI APPROACH

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Voronoi diagrams have recently received attention as data structures containing significant information about the spatial adjacency of map objects. Despite their theoretical efficiency, batch construction techniques require complete rebuilding after each modification. Incremental Voronoi creation methods use processes such as insert, delete and move for points, and from these derive insertion and deletion of lines. With these tools a Voronoi spatial data structure may be maintained dynamically while the input data is being modified.

This approach permits data base querying immediately after modification (a feature not always available) plus more intelligent editing. Dynamic maintenance permits development of interactive polygon building and digitizing systems, including real-time trapping of line crossings. As all updating of polygon sets is performed by incremental operations a temporal log of these may be maintained. This is of value in forestry, among other fields, where previous activities in an area are needed to assess future management practices. Other dynamic applications include area-stealing based interpolation and statistical assessment, and flow modelling where individual particle movement is dependent on the effects of its neighbours.

RÉSUMÉ

Les diagrammes de Voronoi ont récemment retenu l'attention à titre de structures de données contenant suffisamment d'information au sujet de la contiguïté spatiale d'objets cartographiés. Malgré leur rendement théorique, les techniques de construction en lots nécessitent une reconstruction complète, dès modification. Dans les méthodes de création cumulative de Voronoi, on utilise des procédés comme l'insertion, la suppression et le déplacement des points, avec l'insertion et la suppression de lignes qui en dérivent. Avec ces outils, la structure de données spatiales de Voronoi peut être conservée de façon dynamique, alors que les données sont changées.

Cette approche permet de consulter la base de données immédiatement après modification (caractéristique parfois absente) ainsi qu'une présentation plus intelligente. Le caractère dynamique permet de développer des systèmes de numérisation et de construction de polygones interactifs, notamment avec interception des intersections de lignes en temps réel. Comme tous les ensembles de polygones sont mis à jour par des opérations cumulatives, on peut en garder un registre temporaire. Cette caractéristique est intéressante en foresterie, entre autres domaines, car il faut connaître les dernières activités dans un secteur pour évaluer les mesures de gestion suivantes. Parmi les autres applications à caractère dynamique, mentionnons l'interpolation et l'évaluation statistique ainsi que la modélisation de flux, dans laquelle le mouvement d'une particule donnée dépend de l'effet des particules voisines.

INTRODUCTION

To most users of geographic information systems the underlying spatial data structure linking the parts of the map together, along with the way the system designers imagined "space" to be constructed, appear to be of little direct relevance. In this paper, however, I would like to point out that many of the apparently incomprehensible bugs/features of a GIS are directly related to the underlying spatial model used. There is no claim in the following discussions that particular systems are being evaluated, only that certain basic design concepts lead to particular strengths and limitations. Despite the fact that there may be possible "work-arounds" of the underlying limitations, this does not excuse a lack of understanding of the properties of a chosen spatial data structure (SDS) and the underlying perception of space that was used in it (the spatial model).

While much of my research on spatial data structures has been to show that the underlying spatial model may be inadequate, the particular by-product of this research that I want to review here is the importance of the SDS being dynamic. The paper is therefore divided into the following parts:

1) what is a dynamic data structure, together with an example taken from traditional data base management;
2) what are dynamic spatial data structures -- why a traditional SDS is not usually dynamic, and the consequences of it not being dynamic;
3) the importance of understanding the underlying spatial model;
4) the Voronoi spatial model, and a prototype digitizing system;
5) applications where the dynamic property is important.

TRADITIONAL DYNAMIC DATA STRUCTURES

Data Base Management Systems

A dynamic data structure is one that may be fully updated "on the fly". Updates usually consist of insertions and deletions, and are needed in order to permit the searching of the data base in a rapid fashion. This is standard DBMS terminology -- not specifically spatial. In a traditional (non-relational) DBMS there are two parts: the collection of individual records (items, etc.) preserved in a file structure that permits the rapid retrieval of any particular record by its "acquisition number" as with shelved books in a library; and the maintenance of one or more indexes permitting the determination of the "acquisition number" for the desired record. The first part poses relatively little problem; the second, the maintenance of the index, is more difficult.

The basic requirement in a data base "search" is to examine the appropriate index to see if a record having a particular value does exist, and if so where it is (i.e. its acquisition number). For a data base of any size a sequential search of the index would take too long, and hence some form of tree structure is used, permitting

the rapid "zeroing in" on the desired value. Computing scientists have argued long and hard about the best type of tree structure for the usual form of one-dimensional data, and about the desired properties of the tree structure used. To simplify, the B+ tree is now frequently considered a good choice, and its properties will be briefly described, without involving a detailed description.

The B+ tree is a data structure, in that it consists of a set of information combined with pointers permitting all the data items to be examined according to certain rules. It is a tree structure, designed to permit the rapid searching of all index values, starting from some initial point (the root). The process consists of deciding which of several available branches would contain the required value, taking that branch, examining the data item at the resulting node, and recursively asking the same question: which branch do I take next? Clearly a tree with fewer levels will require fewer queries to find an existing index value, and hence obtain the "acquisition number" or record number with which to extract the desired detailed information from the record file. In order to make a tree with the same number of items in it more shallow, there must be an increasing number of children permitted to each parent node. The B+ tree structure allows a fairly large number of children to each parent.

A tree structure is maintained by the insertion and deletion of index values at nodes. Depending on the order of insertion, a tree may become "unbalanced", and most of the new children may, for example, continue to be added to the rightmost node -- hence increasing the tree depth on this side, and not on the other. This negates most of the purpose of a tree, and so techniques are introduced to "balance" the tree (i.e. shift some children to other parents: to those further left in our example). The B+ tree has this property also: all parent nodes are guaranteed to hold at least half of the maximum permitted, and if a node becomes full children are shifted to adjacent parents if possible. If this is not possible the node is split. These processes can be shown to be able to maintain a tree structure with the minimum necessary tree depth, and do it sufficiently rapidly to permit "real-time" maintenance of the data base indexes.

Deletions may similarly affect the balance of the tree. Additional complications arise if the item to be deleted is a parent with many children. Some tree structures do not permit the well behaved removal of parent nodes: there may be no known algorithm for correct deletion without reconstructing the whole tree. If this is the case a "deleted" flag is put in the node so that it will subsequently be ignored, but in reality it still exists in the data structure. This may not matter some of the time, but as records continue to be inserted and deleted the tree inexorably grows, slowing things down and running out of space. A time-consuming "cleanup" program must be then be run to make a new copy of the tree without the deleted "garbage". An indexing system that makes all its updates (especially deletions) rapidly and in full while processing that update is called "dynamic". B+ trees are dynamic.

Finally, in many types of retrieval, after an initial search has discovered a particular key, subsequent retrievals need to obtain the "next" value without a completely new search. In order to handle this frequent occurrence pointers are maintained between the nodes at various levels of the tree in order to fetch the "next" index value without going back to the tree root. The "+" on "B+" indicates this additional property (see Figure 1).

DYNAMIC SPATIAL DATA STRUCTURES

Thus by analogy with data base management systems, any dynamic data structure is one that makes full updates "immediately", rather than re-building later. This applies to spatial data bases in exactly the same way. A truly dynamic data base makes all its updates in full immediately. This applies both to any overlying tree structure (the "B" part, perhaps a quad-tree) as well as to the low-level neighbour-to-neighbour linkages (the "+" part, the "topology" of most spatial data bases). This immediate update ensures that at the next query by the user the full information about the spatial data base, including the immediately previous update, may be used. This is obviously of value if the user is interested in observing what the effect of the previous update would be.

Traditional Spatial Data Structures

Let us suppose that, as in some tree structures, the SDS has no known algorithm for full dynamic "instant" updating of the data base, which consists of a network of polygons. Some batch process must be invoked in order to rebuild the data base after data modification, as this can not be done immediately. It can not be done immediately because, as with our tree-delete example, there is no algorithm implemented to modify "only a part" of the data structure, and therefore the whole thing will have to be rebuilt.

What will be the result of this situation? Clearly the user must perform "today's" updates on "yesterday's" data base, and run the "rebuild" program "this evening". His update procedure will copy a portion of yesterday's map onto the screen and allow him to modify the screen version. Any attempt to query the map immediately will, however, not retrieve all the latest changes until the map is rebuilt. If there is any inconsistency between the GIS query and any immediately-preceding updates then the spatial data structure being used is not dynamic.

In a spatial data structure the "B" part of our data base example, the hierarchical search tree, may or may not exist in a particular implementation; the "+" part, being the lateral linkages between adjacent objects, is necessary in any true vector GIS. As with the data base example, an SDS is non-dynamic when updates, especially deletions, can not be performed quickly enough: the amount of rebuilding may be global, not local in extent. Let us briefly examine why.

A common assumption in the design of a GIS is that boundaries (arcs) initially may be created unrelated to each other. In order to provide the adjacency linkages that must be maintained for subsequent queries, they terminate in nodes, which may connect to other boundaries. If the initial situation is a set of digitized lines, the usual way to find if and where they could connect to other lines and nodes is to test all the possible intersections of line segments. This can be a formidable task, involving much computing time, even without the extensive cleanup required by limited-precision digitizing: e.g. snapping to tolerances; dangling line ends; near-parallel lines that cross. Many algorithms used to create the required linkages treat it as a destructive task: i.e. "yesterday's" map is broken into its original line segments, the updates are added and the map re-built by intersection testing. This approach is by its very nature a global operation, hence by no means instantaneous, and thus not dynamic.

Consequences of Non-Dynamic Spatial Data Structures

What are the consequences of this strategy? Does it limit the effectiveness of GIS's? Would a truly dynamic SDS really help? Let us first examine the known limitations. These are based on one clear statement: lack of a dynamic SDS prevents immediate query of an updated map. Where would this matter?

Perhaps the most fundamental bottleneck occurs with the data entry phase. As anyone who has ever worked with a non-interactive digitizing system has painfully learned, absence of feedback multiplies digitizing effort several-fold. This is true when there is no screen feedback to tell the operator where his cursor is, and which parts of the map have been drawn. It is equally true when the operator is unable to be sure if the computer has registered a connection between the current and pre-existing lines. He can usually tell when his "pen" draws a line that meets a pre-existing line: why can't the computer?

The reason is the same as for the topology building example: this intersection testing is usually thought of as a global rebuilding problem, and not amenable to line-at-a-time updating. Thus in order to tell if the line currently being drawn is crossing, or is about to cross, a previously defined line the whole map would have to be rebuilt after every line segment. Indeed, if we wanted to test if a line crossed itself we would have to rebuild after every digitized point!

Another minor issue concerns the "tracking" of the cursor used by the operator. For polygon maps (only a subset of the types of maps needed in a GIS) this means resolving the "point-in-polygon problem". This is traditionally handled by counting the number of intersections between the boundary segments of the polygon being considered and a line drawn from the cursor to some exterior point. Although this can be speeded up by checking the X-Y extent of all the polygons, there are clearly many calculations to be performed.

Even without further analysis, it appears clear that the "lines are connected if we can find an intersection" approach would have great difficulty in keeping up with even a slow operator if global intersection algorithms are used. This leaves two alternatives: either the line intersection approach must become a local, and thus rapid and dynamic, method; or the line intersection model must be re-thought.

THE IMPORTANCE OF THE SPATIAL MODEL

We have already seen that "dynamic" update depends on the rapid local processing of spatial updates, and that this local processing is a function of the spatial model used. The traditional spatial models available are "raster" and "vector", but this distinction needs some clarification. The raster model assumes that data points are organized on a regular (usually square) grid: i.e. that a universal discrete coordinate system exists. Within this framework the explicit specification of the coordinates of each data point is unnecessary, as this is defined by the ordering of the observations themselves. Less obviously, but of equal importance, this ordering also identifies the neighbouring observations to some central data point of interest (e.g. the 4- or 8- neighbours).

The vector model, in contrast, does not depend on a particular coordinate system. Although point locations will usually be expressed in that form, they can easily be transformed without disturbing any spatial relations. There is no obvious ordering of the data, and no clear neighbour relationships between unconnected map objects (e.g. points and lines). Hence the advantages of the raster model for many applications. Since neighbour and order relationships are necessary for most GIS work, this must be imposed in some fashion. For point data the approach was unclear prior to the development of TIN models, and for line data (e.g. polygons) the ordering/neighbour relationships were imposed by detecting the intersections of the various line segments with each other, in the hope of generating a consistent "graph" of the data that would thus specify the ordering/neighbour relationships. This has worked fairly well, despite the agonies of data entry and verification, and the complexities of handling any remaining unconnected map portions, e.g. islands and isolated point data.

More recent work has reduced the nastiness of these issues somewhat, by allowing a) global search to some starting location and b) local traversal of polygons, areas and nodes to permit local update of the map (Herring, 1987). The topological properties described in this paper permit the local update of polygon-arc-node data structures, including local processing of intersections. In this spatial model independant points are embedded within the appropriate polygon, permitting the formation of the whole map into one graph for subsequent interrogation.

It is, however, possible to re-think the spatial model at another level in order to produce the desired dynamic properties, and this approach may have advantages for some applications.

THE VORONOI SPATIAL MODEL

This model was developed on the underlying assumption that map objects were not necessarily connected -- the initial problem was interpolation from arbitrarily distributed data (Gold, 1989). Spatial ordering and neighbourhood relationships were just as necessary when selecting "adjacent" data points for averaging as in the case of supposedly-connected polygons. How can an order or adjacency be imposed on unconnected objects?

The solution, to this and a growing number of related problems, turned out to be the Voronoi diagram, which is a tiling of the plane that assigns each possible map location to its nearest data object. The result, for point data, is a set of convex polygons ("bubbles"), each with a data point as its nucleus (Figure 2). The common boundaries between bubbles indicate when they are adjacent, and this set of adjacencies forms the Delaunay triangulation, which is frequently seen in TIN terrain models. From its very definition, this triangulation is unique for any particular data set. In addition to providing a consistent definition of adjacency for unconnected objects, the triangulation can also be used to specify a spatial partial-ordering with respect to some view-point location (Gold, 1987). Since the triangulation is the network of all adjacency relationships, where adjacency means that two "bubbles" have a common boundary, the Delaunay triangulation is the spatial data structure for the Voronoi spatial model. Each map object has an associated bubble, or tile, and the collection of these bubbles tile the map area completely.

The "nearest" definition for assigning any location on the map to a specific map object or tile is not restricted to point data: it is completely general. Subsequent work has concentrated on the Voronoi diagrams of points plus line segments. To achieve this, however, the concept of "navigating" a map must be reviewed.

Map Navigation

If, at all times, the spatial adjacency structure of the map is to be retained, then it should be possible to take a data point and steer it through the network -- without breaking the network of triangles that express the spatial relationships of the tiles or bubbles making up the map. (The utility of this process will be seen shortly.) If one visualizes the situation as a set of contiguous bubbles, then it is easy to imagine that one of them could be moved as a local process while disarranging only its immediate neighbours. (It is this property that guarantees the purely local update of the Delaunay triangulation.) The details of this process have been described elsewhere (Gold, 1990b).

Once a point may be moved through space using purely local processes, a few simple modifications permit more complex operations. For example, the creation of a new data point may be achieved by: A) a simple search to find a nearby existing point; B) splitting this one bubble into two, creating a new bubble and data

point by "cellular fission"; and C) moving this new point (and its bubble) to its final destination. Deletion of the point follows the same scheme in reverse, in all cases preserving the spatial data structure (the Delaunay triangulation).

The creation of line segments follows directly. Since a line is the locus of a moving point, the previous split/move process may, if desired, be used to create a trailing line segment that preserves all the adjacency relationships of the point during its travels. Figure 3 shows the Voronoi regions formed around a set of points, followed by the result of generating a line segment as just described. Further details are found in Gold (1990b).

The Digitizing Process

All of these operations are local, and rapid. Visualizing the moving point as the cursor of a digitizer, line segments and points may be constructed as they are defined and inserted directly into the data structure. Since the moving point is functionally equivalent to a pen or cursor, including pen up/down equivalents, usage is almost intuitive. The result of the foregoing spatial model is a "bubble map", with each point or line segment being the nucleus of a tile or bubble. These tiles are convex for point sets, but include parabolic boundaries between adjacent points and lines for sets of points plus line segments. Potential applications for these bubbles include "area-stealing" interpolation (Gold 1989) and polygon skeleton generation (Gold 1990b) for centroid or labelling applications, as well as missing census district type interpolation (e.g. Gold 1990a).

At any moment in time the "pen" has its own bubble, and hence its own set of neighbours. Examination of this neighbour set permits ready navigation of the "obstacles" already in its path, including previous parts of the current line segment. Thus too-close approach to a neighbouring object may, depending upon the application or situation, trigger an intersection operation, a snapping-to operation or a rejection operation whereby a collision-avoidance mechanism prevents pen coordinates from intersecting an existing object. This forms the basis of "Navigator", an attempt at an intelligent digitizer, that is presently under development. This is intended to be a proof-of-concept of the Voronoi or "bubble" spatial model. It is hoped that subsequent projects will follow.

The "invasive" navigation process just described serves to update the data structure with a moving point. A "non-invasive" query also exists that steps through the data structure, maintaining the "current closest object" to the cursor -- which is merely the tile within which the cursor falls. This automatic flagging of the closest object permits easy connection of polygon boundary segments. As line segments have two sides, the tile for a line segment has two parts, one for each side. Thus polygons are defined as the sum of the relevant tiles (Figure 4), and are not explicitly stored as data records. They may, however, be labelled by pointing at any appropriate tile within a boundary composed of points and

line segments, and labelling the other interior tiles by a triangulation-based form of flood-fill algorithm. It is also worth noting that the non-invasive query is equivalent to the point-in-polygon problem, thus providing an elegant local solution to this problem rather than the line-intersection method previously described.

APPLICATIONS OF A DYNAMIC SPATIAL DATA STRUCTURE

In the previous digitizing application, immediate query would permit immediate updating of data entry errors -- whether unwanted line crossings, dangles, gaps, unclosed polygons, etc. This would certainly speed up the normal digitizing process, as the human preference is to complete a portion of a map while one is thinking about, and understands, it. Temporal skipping (waiting for the rebuild operation) is even worse than spatial skipping (looking back and forth between map, screen, keyboard, etc.)

Immediate query could be used in a variety of other GIS applications, where its absence is a continual irritant. Any time that a sequence of changes are desired, with the next change depending on examining the previous one, waiting until "tomorrow" is at the least annoying, and frequently worse. Examples include landscape modelling, where it is desirable to try one layout of the grounds, examine it, make small changes, and repeat the process. It is hard to remember what one was thinking about yesterday when a change was made, and even worse to remember choices made before that! Any type of "what-if" modelling that depends on significant user interaction is therefore all but precluded by non-dynamic SDS's. A particular example is forest management, where the economic consequences of a forest cutting decision need to be evaluated and adjusted in an iterative fashion in order to achieve both economic and environmental objectives.

Time based GIS may sometimes be considered to consist of the sequential insertion and deletion of map objects (e.g. polygons and boundaries), as in the frames of a movie. This is not viable without a dynamic SDS.

Area-stealing interpolation involves the insertion and deletion of the sampling point (Gold, 1989). Again, only dynamic maintenance makes this feasible. In the case of statistical estimates the data points themselves need to be deleted and re-inserted (Gold, 1990a).

Any type of flow modelling, where individual particle movement depends on the action of its neighbours, is all but prohibitive without dynamic SDS's. Finite difference methods may be possible, because the attribute data base may be updated dynamically, as the polygons themselves need not move. This, however, only emphasizes the handicap of using a spatial data structure without dynamic update. If it is available for attribute data, it should exist for spatial data!

CONCLUSIONS

I have reviewed the basics of dynamic data structures, both traditional and spatial, and examined the reasons why dynamism is not always easy to achieve. The importance of the underlying spatial assumptions has been emphasized, and a new spatial model -- the Voronoi -- proposed. Recently gained experience, e.g. at the previous EGIS conference and in a new position in a research chair in forestry and geomatics, suggests that major concerns of operational GIS usage centre partly on rapid "what-if" queries after data modification, and even more on the ability to update a map and validate that update in the same session, thus dramatically reducing the time taken to complete data input or updating. While not necessarily the appropriate approach when raw data is received in a batch form, e.g. from scanning, a large number of GIS operations would greatly benefit from the existence of a truly dynamic spatial data structure. It is hoped that the proposed Voronoi spatial model, being the basis for one fully dynamic spatial data structure, will be found useful in a variety of applications.

ACKNOWLEDGEMENTS

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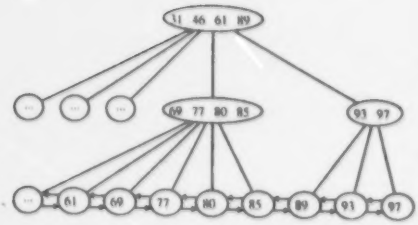

Figure 1. Part of a B+ tree, showing the pointer structure.

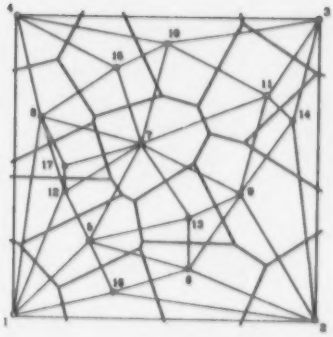

Figure 2. The Voronoi regions of a simple point data set, showing the Delaunay triangulation.

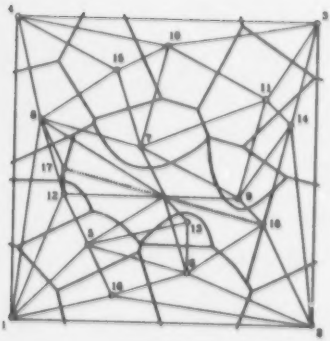

Figure 3. The point set of Fig. 2 with a line segment developed as point 18 was split from point 17 and moved away.

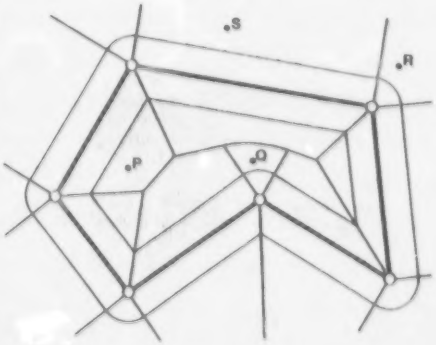

Figure 4. A simple polygon and associated Voronoi regions: points P and Q are inside, R and S outside. Also shown is a buffer zone around the polygon boundary.

GIS CONFERENCE

TITLE: AN INVESTIGATION OF DATA STRUCTURES TO REPRESENT GEOREFERENCED COASTAL INFORMATION

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ABSTRACT

A prototype GIS system has been developed to evaluate the functionality of various data structures to represent coastal information. This work follows on previous work which developed a system using DBMS technology and modeled the coast as line segments. This study compares models using line segments, redundant lines, lines with reduced redundancy, buffered lines, and polygons for functionality and efficiency of update and query. The prototype uses coastal data collected by the Atlantic Geoscience Centre for the geographic area covered by NTS 12 B 1-250,000 topographic sheet (Stephenville, Newfoundland). The prototype system was developed using ESRI's PC ARC/INFO system.

ÉTUDE DE STRUCTURES DE DONNÉES POUR LA REPRÉSENTATION D'INFORMATION CÔTIÈRE À RÉFÉRENCE GÉOGRAPHIQUE

RÉSUMÉ

On a mis au point un prototype de SIG pour évaluer la fonctionnalité de diverses structures de données afin de représenter des informations côtières. Ce travail fait suite à la mise au point d'un système au moyen de la technologie du SGBD et de la modélisation de la côte en segments de lignes. Dans l'étude présentée ici, on compare des modèles à segments de lignes, à lignes redondantes, à lignes de redondance réduite, à lignes tamponnées et à polygones, au point de vue de la fonctionnalité et du rendement à la mise à jour et à la consultation. Le prototype s'emploie avec des données côtières recueillies par le Centre géoscientifique dans la zone géographique correspondant à la carte du SNRC 12 B 1-2500 (Stephenville, Terre-Neuve). Le prototype a été mis au point au moyen d'un système PC ARC/INFO d'ESRI.

USE OF THE SPANS GIS IN THE DEVELOPMENT OF AN ECOSYSTEM MANAGEMENT MODEL FOR THE CENTRAL CANADIAN ROCKIES ECOSYSTEM

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The Canadian Rockies is one of the last predominantly wildland ecosystems remaining in the Earth's temperate region. Most of the area is protected in national parks, provincial parks and wilderness areas. Despite a significant level of protection, development immediately outside of park boundaries and within the parks themselves threatens the continued ecological integrity of the entire ecosystem.

The Canadian Rockies Ecosystem Interagency Management (CREIM) Project is a coordinated effort to integrate a vast amount of biophysical data that can be used as a basis for ecosystem planning. The TYDAC SPANS GIS was used to consolidate a wide array of biophysical data sets including vector, raster and thematic information. Data sets included National Topographic Survey (NTS) topographical data, a Thematic Mapper (TM) derived vegetation map, a digital elevation model (DEM), wildlife data, management unit and zoning information and visitor use data. Overlay techniques and modelling procedures were used to prepare a cumulative impact assessment model of existing development. The challenges of interagency cooperation and future uses of GIS for ecosystem management in national parks is discussed.

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UTILISATION DES SPANS SIG POUR LA MISE AU POINT D'UN MODÈLE DE GESTION DES ÉCOSYSTÈMES APPLICABLE À LA ZONE CENTRALE DES ROCHEUSES

RÉSUMÉ

Les Rocheuses canadiennes sont parmi les derniers écosystèmes essentiellement sauvages qui restent dans la zone tempérée de la planète. On a protégé la plus grande partie de cette région en y créant des parcs nationaux, des parcs provinciaux et des réserves fauniques. Malgré cette protection considérable, le développement qui se fait en bordure des parcs et à l'intérieur de leurs limites met en danger l'intégrité écologique de l'écosystème dans son ensemble.

Le Projet de l'écosystème de la zone centrale des Rocheuses canadiennes met en collaboration divers organismes en vue d'intégrer une énorme quantité de données écologiques pouvant servir de base pour la gestion de l'écosystème. On a employé le SPANS SIG pour regrouper toute une variété d'ensembles de données écologiques, notamment de l'information vectorielle, matricielle et thématique. Entre autres, on a ainsi regroupé des données cartographiques du SNRC, une carte des formations végétales produite avec des données thématiques, un modèle numérique d'altitude, des données sur la faune, des renseignements sur les projets de développement et de zonage et des données sur les visites. On s'est servi de techniques de superposition et de modélisation pour préparer un modèle d'évaluation de l'impact cumulatif du développement déjà réalisé. On traite aussi de la collaboration entre les organismes participant au projet et des usages auxquels le SIG pourrait servir en gestion des écosystèmes dans les parcs nationaux.

1.0 INTRODUCTION

Many of the national parks in North America were established at a time when the expediency of political and recreational demands were responsible for the establishment of park boundaries, rather than creating borders based on the need to protect entire ecosystems. As a result, the legal boundaries of these parks are far smaller in size than the biotic requirements of maintaining a full complement of species (Newmark 1985). This is particularly true for those large mobile species which may spend part of their life cycle in areas outside of the protected confines of national parks, such as the grizzly bear (Herrero 1985). To date, this problem seems to be confined to most of the national parks within the continental United States and the smaller national parks of eastern Canada (Newmark 1987; Glenn and Nudds 1989). In the Rocky Mountains, only the combined protected areas of Jasper, Banff, Yoho and Kootenay national parks are large enough in size to have withstood any species loss since the time of park establishment (Newmark 1987).

Despite their size, the integrity of the four mountain parks is threatened by expanding resource development immediately outside of the park boundaries and increasing human activities within the parks themselves. It has become evident that cooperative management agreements between adjoining jurisdictions will be required if the integrity of our national parks is to be assured into the next century. With this thought in mind, the Canadian Parks Service has launched the Canadian Rockies Ecosystem Interagency Management (CREIM) Project to initiate management approaches similar to those developed for the successful biosphere reserve on lands surrounding the periphery of Waterton Lakes National Park (Francis 1987).

The CREIM Project encompasses a 40,631 km^2 area that straddles the continental divide of Alberta and British Columbia. The study area includes the protected core areas of Banff, Yoho and Kootenay national parks, and extends west to the Columbia River trench and eastward along the eastern slopes of Alberta. It is bordered to the north by the Greater Jasper Ecosystem and to the south by the Crown of the Continent Ecosystem which extends into the United States. Together, these three ecosystem areas may constitute a Carnivore Conservation Area as proposed by World Wildlife Fund Canada (Hummel and Pettigrew 1991). Both federal and provincial jurisdictions are currently involved in the planning process including the Canadian Parks Service, Alberta Forestry, Lands and Wildlife, Alberta Recreation and Parks, B.C. Lands and Forests and B.C. Environment and Parks. Initial meetings of this Canadian Rockies Ecosystem Interagency Advisory Group (CREIAG) have defined the boundaries of the CREIM Project and have produced an agreement to establish a digital database for the ecosystem area.

One of the major problems involved in effectively managing an ecosystem with the dimensions of the CREIM Project area, is the sheer size of the area itself and the correspondingly small volume of biophysical data that is available. Until recently, ecosystem considerations have not been central to planning within national parks, and both staff and budget limitations have necessitated the mapping of biophysical information at small scales (1:50,000 and smaller). Much of the known information about wildlife populations in the parks has been extrapolated from these studies, augmented by a number of species specific research projects that have been undertaken in much smaller study areas. Outside of the national parks, biophysical mapping programs have also been initiated at small scales (1:100,000 and smaller) and the commitment to both wildlife and ecological research has been on a lesser scale than that conducted within

national parks. Because of the differences in jurisdictional responsibilities between federal and provincial agencies, each jurisdiction has developed its own limited information base in isolation and consequently, a comprehensive data base for the larger ecosystem has not developed. As a result, management decisions within each jurisdiction have relied heavily on the staff experience of line agencies and may be influenced more by localized concerns than concerns of the greater ecosystem itself.

The recent advances in GIS technology may offer a solution to solving many of the interagency problems involved in ecosystem management. By assembling data for the entire area in "one pot", managers can begin to view their responsibilities from the perspective of the ecosystem outside of their narrow jurisdictional focus. GIS can offer many of the same benefits as did the earlier mathematical modelling procedures involved in adaptive environmental management (Holling 1978). The following paper discusses how such an approach has been taken to develop an ecosystem model for the Canadian Rockies Ecosystem and discusses some of the challenges facing GIS technology and its use by resource managers.

2.0 THE USE OF GIS IN NATIONAL PARK MANAGEMENT IN NORTH AMERICA

GIS use in North American national parks is showing rapid increases in both Canada and the United States, but is evolving in much different directions. In Canada, a commitment to the DOS based SPANS system (INTERA TYDAC Technologies Ltd., Ottawa) was made by Environment Canada and the first GIS installation became operative in the Canadian Parks Service (CPS) national headquarters in June 1987. Today, there are 32 SPANS systems in operation in CPS offices across Canada. All SPANS systems are PC based and run under DOS or the OS/2 operating system (David Welch pers. comm.).

The first installation of GIS within the U.S. National Park Service was made in 1986. There are now 53 GIS installations across the country, including installations in 35 national parks. The U.S. National Parks Service has made a commitment to the UNIX based GRASS system which appears to be developing as a standard platform in use by U.S. government agencies.

In Canada, the use of GIS in national park management is largely at the park level with the bulk of activity currently being directed at the completion of baseline databases. Use of GIS largely falls into three categories that correspond with various phases of park management.

1. Inventory - compilation of thematic databases (e.g., landforms, soils, vegetation) as part of the Resource Description and Analysis (RDA) phase.

2. Management - currently being used to generate fire management plans in several parks (e.g., Wood Buffalo and Pukaswa) and ecosystem models for Fundy National Park and Banff/Yoho/Kootenay national parks as part of the development of Conservation Plans and Park Management Plans.

3. Environmental Impact Assessment - currently being used in the Environmental Assessment and Review Process to assess the impacts of development in Prairie region national parks.

For a review of use of GIS in U.S. national parks, readers are referred to the works of Waggoner (1991) and others presented in the May 1991 issue of GIS World.

3.0 PROJECT OBJECTIVES

The intent of the CREIM Project at this stage is not to model the entire ecosystem per se, but rather to assemble existing digital and hard copy information for the study area and to involve the various federal and provincial agencies in understanding how a geographical information system could be of use in managing complex inter-jurisdictional problems. It is obvious at the present time that there is an overall lack of useful data and that the available information has been assembled at a variety of map scales and utilizing differing systems of classification. An additional benefit of the CREIM Project will be to understand where data gaps currently exist and to direct additional research needs thereby avoiding redundancy between the adjoining jurisdictions. Ultimately, it may lead to the adoption of a set of common mapping standards and conventions to be used by all agencies.

It is our hope that once the database has been fully assembled and validated, the use of modelling procedures within the GIS software can be used to develop simulation procedures for a wide range of management activities, such as fire management, the siting of resource extraction activities, the setting of hunting regulations, the siting of trails and facilities, etc.

4.0 SOURCES OF INFORMATION

Because of the large size of the study area, involving multiple jurisdictions and mapping responsibilities, a wide range of data sources were involved in the CREIM Project.

4.1 Current Data Sources

At the present time, use is being made of the following data sets:

1. National Topographic Survey, Energy Mines and Resources (EMR) 1:250,000 scale digital data. The study area covers 6 NTS map sheets at this scale. Using the EMR information, vector files were made of roads, hydrography, contours and political boundaries. A digital elevation model (DEM) was also established from the NTS data. The work was completed by S.L. Ross Environmental Services Ltd., and INTERA TYDAC Technologies Ltd., Ottawa.

2. Vegetative Cover Map. INTERA Technologies Ltd., Calgary was contracted to prepare a vegetative cover map using Thematic Mapper satellite imagery and 1:250,000 scale digital terrain elevation data provided by EMR. A classified raster of vegetative cover

was produced and converted to a SPANS quadded map file.

3. Human Activity Maps. Within each of the three national parks, trails, linear developments (e.g., pipeline right-of-ways, roads, etc.) and facilities were digitized from 1:50,000 scale maps using, in part, information provided by the Banff Warden Service.

4. Canada Land Inventory - Ungulates. Digital data files at a 1:250,000 scale were obtained from Environment Canada, Ottawa and input into the study area universe. The CLI data did not include any information within national park boundaries.

5. Ecological Land Classification Data. 1:50,000 scale digital data from the ELC conducted in Banff, Yoho and Kootenay national parks was obtained from the CANSIS system of Agriculture Canada. The files were converted into SPANS thematic maps of vegetative cover and wildlife habitat capability for a number of key wildlife species.

6. Zoning Maps. Using information provided by provincial agencies in B.C. and Alberta and using 1:250,000 scale NTS topographic maps as a base, zoning maps were derived.

7. Wildlife Management Unit Maps. Wildlife management unit maps for Banff National Park and areas contained within the jurisdictions of Alberta and British Columbia were mapped on 1:250,000 scale NTS base map sheets.

8. Wildlife Distribution Data. Wildlife species distribution maps were produced within each of the three national parks using data derived from studies of elk, grizzly and black bears and wolves.

4.2 Future Data Sources

Additional sources of information that will be added to the ecosystem management model may include the following:

1. 1:20,000 TRIM (Terrain Management Information System) base map data and DEM information from Maps B.C. This will be particularly useful for secondary roads.

2. 1:20,000 digital base map and DEM information from Maps Alberta. This will be particularly useful for secondary roads.

3. Digitizing of hardcopy maps of Integrated Resource Plans for Alberta's Eastern Slope showing zoning and ecological land classification units at a 1:100,000 scale.

4. Digital information from the Provincial Forest Services in Alberta and B.C. This information will include forest cover, stand age and company operating plans.

5. Location of oil and gas facilities from databases held by the Alberta Energy Resources Conservation Board.

6. Digital information collected by B.C. Hydro as part of the Mica Compensation Project.

7. Incorporation of a more accurate DEM either at a 1:50,000 or 1:20,000 scale within the national park boundaries using stereo pair SPOT data.

At the time of writing, we are awaiting additional information that is essential to mapping of the CREIM Project area. A full presentation of results will be made available at the GIS '92 conference in March.

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AN EXPERT SYSTEM INTEGRATED WITH GIS FOR LAND SUITABILITY EVALUATION FOR AGRICULTURE

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ABSTRACT

Land suitability evaluation for agriculture includes two major characteristics: the spatial characteristic and the constraint characteristic. A series of spatially-related tasks need to be undertaken before suitability evaluations are carried out. This involves collecting, storing, manipulating, and presenting of land information. Geographical Information Systems (GISs) provide powerful tools for these purposes. The constraint characteristic, however, involves inference based on the heuristics of crop growing conditions. The more factors are taken into account, the more complex the inference becomes. Expert System (ES) technology is therefore an appropriate approach to this problem-solving. In addition to conducting suitability evaluation, an expert system can also provide justifications for its evaluation results and adjust its behavior dynamically.

Based on these considerations, a prototype expert system is being developed for the evaluation of land suitability for agriculture. The spatially related geographical data which are stored in the PAMAP, a PC-based GIS, are imported into the expert system through the Dbase III. The prototype system consists of five modules: the interface with users, the inference engine, the knowledge base, the knowledge acquisition mechanism, and the

interface with the Dbase III. Using crop growing knowledge, the system will evaluate land suitabilities based on soil units, and provide crop growing suggestions for agriculture decision making. The evaluated results will be imported into PAMAP for presentations. Upon request, the expert system will be able to give explanations for HOW an conclusion is reached and for WHY additional information is needed. The knowledge contained in the system will be able to be updated through the knowledge acquisition module. The region of Ontario is being used as an experimental area.

INTÉGRATION D'UN SYSTÈME EXPERT ET D'UN SIG POUR L'ÉVALUATION DES POSSIBILITÉS DES TERRES POUR L'AGRICULTURE

RÉSUMÉ

L'évaluation des possibilités des terres pour l'agriculture comporte deux grandes caractéristiques : des caractéristiques spatiales et des caractéristiques de contrainte. Il faut exécuter une série de tâches relatives aux données spatiales avant de pouvoir effectuer l'évaluation des possibilités. Il s'agit de recueillir, de stocker, de manipuler et de présenter les données sur les terres. Les systèmes d'information géographique (SIG) offrent de puissants outils à ces fins. La contrainte est toutefois qu'il faut procéder par inférence à partir de l'heuristique des conditions de croissance des cultures. Plus les facteurs pris en considération sont nombreux, plus l'inférence devient compliquée. La technologie des systèmes experts (SE) devient donc un outil approprié pour résoudre ce type de problème. Un système expert, en plus d'effectuer une évaluation des possibilités, peut justifier les résultats de son évaluation et peut adapter son comportement de façon dynamique.

Un prototype de système expert est actuellement mis au point à des fins d'évaluation des possibilités des terres pour l'agriculture à partir de ces considérations. Les données pointées géographiquement qui sont stockées dans le PAMAP, un SIG fonctionnant sur PC, sont importées dans le système expert par l'intermédiaire de la Dbase III. Le prototype du système comporte cinq modules, soit l'interface utilisateur, le moteur d'inférence, la base de connaissances, le mécanisme d'acquisition de connaissances et l'interface avec la Dbase III. À l'aide de ses connaissances sur la croissance des cultures, le système évaluera les possibilités des terres à partir des unités pédologiques et suggèrera des cultures dans le cadre d'un processus décisionnel sur les cultures. Les résultats évalués seront importés dans le PAMAP à des fins de présentation. Sur demande, le système expert sera en mesure de fournir des explications sur le savoir-comment d'une conclusion et sur le savoir-pourquoi de la nécessité d'information additionnelle. Les connaissances du système pourront être mises à jour par l'intermédiaire du module d'acquisition de connaissances. La région de l'Ontario sert de région expérimentale.

STATISTICAL INTEGRATION OF MULTICHANNEL IMAGERY AND A SOIL EROSION DATABASE USING A HYBRID IMAGE PROCESSING AND GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

A multivariate approach was employed which uses two methods, principal component analysis, PCA, and min/max autocorrelation factor analysis, MAF, to reduce the number of bands and to generate enhancements in a LANDSAT TM image and a SPOT image of a study area in the Cochabamba Valley, central Bolivia. Input to the analysis are six TM bands and three SPOT bands, previously edge enhanced by filtering using a 3x3 kernel. The results considerably improved the detection of vegetation and landuse to be incorporated in a model to predict the rate of soil loss due to erosion by water. Fieldwork and a soil erosion susceptibility map were used to derive soil parameters required for an erosion assessment. A recoding of the complex map unit symbology was performed to obtain a database of polygon attributes to facilitate management and interaction.

Image processing by mathematical morphology and contextual analysis helped to delineate soil characteristics related to soil erosion evaluation. Characteristics such as stoniness and superficial texture were inferred from multitemporal satellite image analysis (i.e., SPOT and TM from different seasons). Landcover and slope length were also determined using other image processing techniques. These characteristics were then transferred to a non-spatial database to run the erosion model in a GIS. The erosion classes which came from the model were then displayed onto the satellite data and the corresponding reflectance values were then used to extrapolate those classes to the rest of the study area. For the analysis, ILWIS, the Integrated Land and Water Information System programmed at ITC was used and interfaced with external software for multivariate statistical analysis. In the paper, considerations are also made on the advantages of a hybrid system for image processing, GIS and statistical analysis.

INTÉGRATION STATISTIQUE DE L'IMAGERIE MULTICANAL ET D'UNE BASE DE DONNÉES SUR L'ÉROSION DES SOLS À L'AIDE D'UN SYSTÈME HYBRIDE D'INFORMATION GÉOGRAPHIQUE ET DE TRAITEMENT D'IMAGES

RÉSUMÉ

Nous avons eu recours à une approche multivariable qui fait appel à deux méthodes, soit l'analyse des composantes principales et l'analyse des facteurs d'autocorrélation min./max. pour réduire le nombre de bandes et pour accentuer des images du capteur thématique LANDSAT et du SPOT d'une région d'étude située dans la vallée de Cochabamba, dans le centre de la Bolivi . Les données d'analyse proviennent de six bandes du capteur thématique et de trois bandes du SPOT dont les bords ont été précédemment accentués par techniques de filtrage à l'aide d'un noyau de 3 sur 3. Les résultats ont beaucoup amélioré la détection de la végétation et de l'utilisation des terres devant figurer dans un modèle destiné à prévoir le rythme d'effrittement du sol causé par l'érosion hydrique. Des travaux sur le terrain ont été effectués et une carte de la sensibilité des sols à l'érosion a été dressée pour obtenir les paramètres du sol nécessaires à une évaluation de l'érosion. De nouveaux codes ont été attribués aux symboles de l'unité cartographique complexe afin d'obtenir une base de données des attributs des polygones et de faciliter la gestion et l'interaction.

Le traitement des images par analyse contextuelle et morphologique mathématique a aidé à délimiter les caractéristiques du sol liées à l'évaluation de l'érosion du sol. Des caractéristiques comme la pierrosité et la texture en surface ont été déduites de l'analyse d'images satellitaires multidates (dans le cas présent, du SPOT et du capteur thématique prises à différentes saisons). Le couvert végétal et la longueur de pente ont également été déterminés à l'aide d'autres techniques de traitement des images. Ces caractéristiques ont ensuite été transférées à une base de données non spatiales pour permettre le passage du modèle d'érosion dans un SIG. Les classes d'érosion qui provenaient du modèle ont ensuite été superposées à des donnée satellitaires et les valeurs de réflectance correspondantes ont ensuite servi à extrapoler ces classes au reste de la région à l'étude. Le système intégré d'information sur les terres et les eaux (ILWS) programmé à l'ITC a ensuite été utilisé pour l'analyse et interfacé avec un logiciel externe à des fins d'analyse statistique multivariable. Le présent document fait également état des avantages d'un système hybride pour le traitement des images, un SIG et l'analyse statistique.

USE AND MAINTENANCE OF CADASTRAL DATA IN A GIS FOR CANADA LANDS

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Abstract

Recently many government agencies have implemented various approaches to manage cadastral survey information. Most of these systems have been in response to the need to automate land ownership records. Legal Surveys Division is implementing a cadastral data management system which will allow various uses to be made of the data. This paper will discuss the uses which will be made of the cadastral survey data in the Automated Canada Lands Information System (ACLIS) by various other federal government departments and the territorial governments. A cadastral data management system is being employed to ensure efficient maintenance of the data over the long term. The use of this system and the practical implications are presented.

UTILISATION ET MISE À JOUR PAR UN SIG DES DONNÉES CADASTRALES SUR LES TERRES DU CANADA

RÉSUMÉ

Depuis peu, de nombreux organismes gouvernementaux ont eu recours à diverses approches pour gérer les données provenant des levés cadastraux. La plupart de ces systèmes ont été mis sur pied en réponse aux besoins croissants d'automatisation des registres cadastraux. La Division des levés officiels met actuellement en place un système de gestion des données cadastrales qui permettra diverses utilisations de ces données. Le présent article porte sur les utilisations des données du Système automatisé d'information sur les terres du Canada (SAITC) pour les divers autres ministères fédéraux et les gouvernements territoriaux. Un système de gestion des données cadastrales est utilisé pour s'assurer que ces données seront tenues à jour de façon efficace à long terme. L'utilisation de ce système et ses incidences pratiques sont également présentées.

INTRODUCTION

Legal Surveys Division has developed a geographical information system (GIS) for retrieving and managing monument, boundary, and parcel information and documents pertaining to Crown Canada Lands. This Property Fabric Information System (PFIS) will help improve information management in all operational areas of the Division, including survey records, survey standards and other technical and administrative areas. The PFIS provides the dynamic cadastre required for automated registry systems. It is dynamic in the sense that it can be continuously updated with new survey information upon which new land interests are being registered.

The Surveyor General of Canada Lands has the legislated responsibility for managing legal surveys, and records of those surveys, for approximately 2300 Indian Reserves across Canada, for all National Parks, and for public and private lands in the Yukon and Northwest Territories. This responsibility also involves managing surveys for native land claims and oil and gas leases within Canada's offshore boundaries. Efficient access is required to the more than 70,000 survey records and numerous volumes of support material that the division has accumulated in more than 100 years of operation as the main federal legal surveys organization in the country. Conventional methods of accessing and managing records can no longer meet the day-to-day information needs of internal users and the various other outside agencies and individuals in the public and private sector.

1. PFIS OBJECTIVES

The objectives of the PFIS are to improve access to survey information and provide a basis for property rights using a measurement based GIS. The system will not contain any derived data or adjusted data. It will only contain legal measurements from official survey plans.

Improved Access to Information

The PFIS gives access to information pertaining to active and superseded survey parcels, to the most recent survey boundaries, and to active and old survey monuments. It also gives access to all documents in the custody of Legal Surveys Division (LSD). The document access is achieved by linking to the Survey Records Information System database to retrieve descriptive information. It provides a means to retrieve not only survey plans, but also other related documents (air photos, maps, etc.) and/or survey projects (project geographic locations, etc). Upon identification of an arbitrary polygon the PFIS will reliably retrieve all plans, related survey documents and/or survey projects which share the same, or part of the same, land area.

A Basis for Property Rights

The PFIS also provides a basis for property rights parcel information management. The other government departments which are responsible for the registration of land interests on Canada Lands are Indian Affairs, Parks Canada and the two territorial governments. The PFIS can provide the full history of all registered interests for a Canada Land area. This feature is made possible by expressing the property rights in terms of the cadastral survey parcels.

2. PFIS DATA

The PFIS stores geometric and descriptive information about entities (i.e. Survey Parcel) (Fig. 1) to meet the system objectives and provide the necessary query capabilities. The descriptive information (i.e. Lot Number) is stored as attributes in the database. The geometric information (i.e. Parcel Shape) is stored as graphic elements (i.e. point, line or polygon) in the graphic files.

Survey Information:

The descriptive information maintained in the system for survey parcels consists of the lot and plan numbers, legal description, plan area and a location description based on the survey system. The attributes maintained for the survey boundaries are the plan distance and direction and the number of the plan from which the values were taken. Survey monument attributes consist of monument and plan numbers; monument type and description; northing and easting; and the action taken on the monument by each plan upon which the point appears. Control monument attributes consist of all geodetic information normally associated with a control point.

Registry Information:

The registry information is organized by registered parcels, leases and easements. The descriptive information maintained for each type of interest consists of an identification number (link to registry databases), description, plan number and area.

Document Information:

The descriptive information maintained for survey documents is organized by survey plans, air photos and projects. A location description based on the survey system can be maintained for each type of document. The survey plan number, air photo flight line number and project numbers are maintained in the system.

3. QUERY CAPABILITIES

The query and analysis capabilities for the PFIS applications were constructed within the relational database management system (RDBMS) (Fig. 2). There is a standard user interface which is similar to other applications in use at Legal Surveys Division. The PFIS allows none graphic querying to be done using basic alphanumeric terminals. Many day-to-day queries for attributes and historical paths can be done without the graphic interface.

Derived information (i.e. parcel history) can be obtained through data manipulation and analysis. This is achieved with the use of attribute relations (table joins) and geometric relations (topology).

The PFIS application issues the appropriate commands to the GIS and RDBMS to perform the desired search and analysis. The GIS and RDBMS share the polygon keys, line keys and node keys. These elements are known to both the GIS and RDBMS and are the link between the descriptive information in the database and the geometric information in the graphic file. This allows users to carry out search and analysis operations by specifying any known attributes or by pointing to graphic objects. The following examples give an overview of some of the operations possible with the PFIS:

- A search can be performed on the RDBMS based on descriptive information (parcel number, plan number, etc) and its geometric representation displayed on the screen by the GIS;

- Parcels, boundaries or monuments can be selected on the graphic screen using a pointing device and the corresponding descriptive information retrieved by the RDBMS;

- An arbitrary polygon can be defined on the graphic screen and all surveyed parcels, registered parcels, survey documents (plans, maps, air photos) and survey projects can be retrieved if part or all of their extent falls within the defined polygon;

- A parcel can be identified and all the survey monument or boundary line information pertaining to it can be retrieved from the RDBMS by using the topology;

- The full history of a parcel can be found;

- A boundary line can be identified and the descriptive information related to the monuments at its ends and the parcels on its left and right can be displayed by the RDBMS;

- A monument can be identified and the descriptive information related to connecting boundaries or surrounding parcels can be displayed by the RDBMS;

- A survey document (survey plans, air photos or projects) can be identified and the corresponding descriptive information of any related documents retrieved by the RDBMS;

- A registered parcel can be identified by an RDBMS attribute search; a polygon overlay is then performed by the GIS to select the corresponding survey parcels and the resulting descriptive information (neighbouring land interests and affected survey parcels) is displayed by the RDBMS.

The PFIS is a valuable tool for project planning and impact assessment for land managers. It can provide the cadastral and registered interest information necessary for development projects. For example (Fig. 3), a new power line right of way may cross over many different land interests. The PFIS allows the user to analyze proposed locations for the right of way. A line is drawn on the graphic to represent the centre line of the right of way. Using the system's buffering capability, a polygon is created around the line with the width of the right of way. The system then can use that polygon in a polygon overlay process to discover all entities which the proposed right of way would affect.

4. Maintenance of Data

Measurement Based GIS

The PFIS is a measurement based GIS. The database only holds data which is shown on official plans. The system contains no derived or adjusted data (except for coordinates). The coordinates required to establish the geometric information are derived from a least squares adjustment performed on the original observations. This methodology allows the accuracy of the database and the graphic representation to be upgraded by inputting new measurements. The coordinates are re-calculated using least squares while assigning a higher weight to those measurements which are more accurate.

The PFIS accepts the following observations (Fig. 4) and constraints (Fig. 5) for the least squares adjustment:

Observations:

a) Point coordinates
b) Distance between two points
c) Azimuth between two points
d) Angle between three points

Constraints:

a) Fixed length
b) Fixed coordinates
c) Straight line
d) Circular curve

e) Parallel lines

Other types of observations can be entered, however they are expressed in terms of the simple observations described above. A circular arc can be entered but the following information would be used in the least squares adjustment:

- A distance observation for the radius,
- An angle observation for the delta, and
- A constraint to keep the curve a circular curve.

All the points required to establish the survey boundaries or any other boundary (i.e. registered interest, easement, etc.) are adjusted simultaneously. This allows the use of observations from different sources in the adjustment process and provides a means to maintain the integrity between the different layers of information.

Only one line can exist between two given points. However, this line can have multiple observations. Similarly, the line can have multiple codes to indicate that different types of boundaries (e.g. survey boundary and registered interest boundary) are sharing the same entity.

The database application sends a series of commands to be executed by the GIS software and assigns each graphic element the appropriate key, layer and feature code. This ensures accurate and precise links between the geometric information and the corresponding descriptive information stored in the database, thereby increasing the reliability of the overall system.

Measurements from new surveys (subdivisions, resurveys, etc.) are verified against the existing data. If the results are acceptable, the new information is added to the database. A least squares adjustment is performed and the changes are reflected in the graphic files.

A Basis for Property Rights

The PFIS provides a basis for property rights parcel information management (Fig. 6) by expressing the property rights (registered interests, easements, etc.) in terms of the survey fabric. If a registered interest boundary is defined by a survey line, then both boundaries share the same geometric definition. If a parcel boundary is defined in terms of a distance from a certain point along a survey line, then 90 degrees from there to another point, the expressed geometry will be preserved (i.e. the parcel boundary will follow the survey boundary, the distance from the survey monument and the 90 degree angle will be preserved). If a parcel boundary is not based on any survey information then it is entered with the information available. With these processes, changes in survey information will be automatically reflected on the property rights layers.

The PFIS incorporates into one survey overlay, both the current and underlying survey

fabric. The survey overlay displays only the current survey fabric; however all underlying surveys are related explicitly to this current fabric through the data base structure. An old parcel is expressed in terms of the new parcels into which it has been subdivided. This provides an historical path to cadastral information and a method of expressing property rights in terms of old survey parcels.

Conclusions

The PFIS allows efficient long term management of the cadastre for Crown Canada Lands. The data model in the PFIS provides an automated method for the management of registry parcels. Because all registry parcels are defined in the PFIS in terms of the survey fabric, all changes to the survey fabric are automatically reflected on the registry layers. This feature ensures that the ownership layers are always in registration with the cadastral layer. The security of the linkages between the descriptive information and the geometric information gives the PFIS a high degree of reliability to all users.

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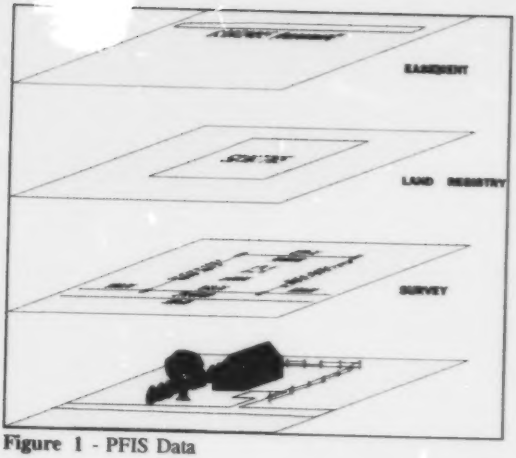

Figure 1 - PFIS Data

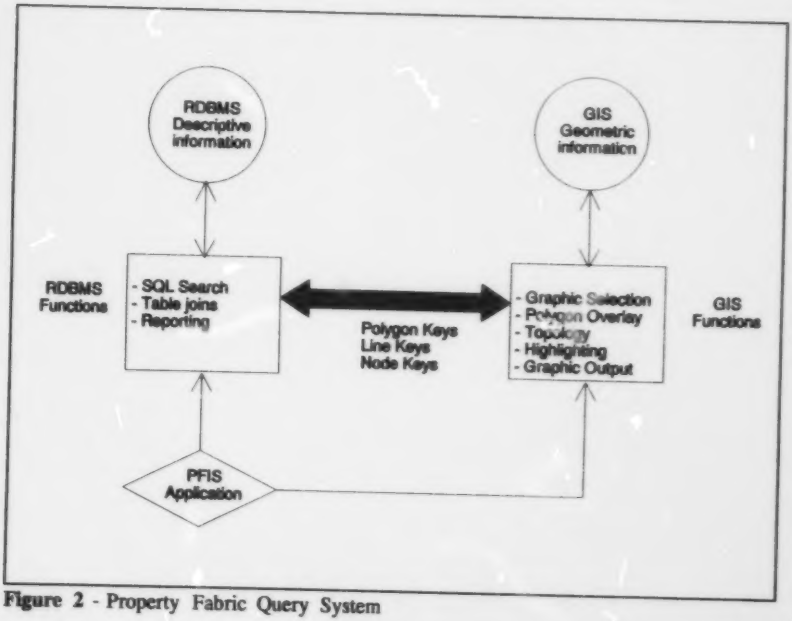

Figure 2 - Property Fabric Query System

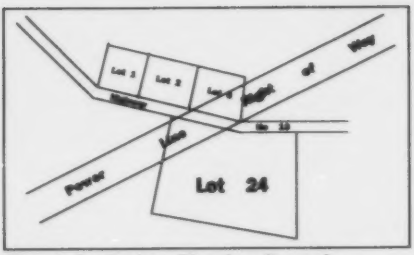

Figure 3 - Project Planning Example

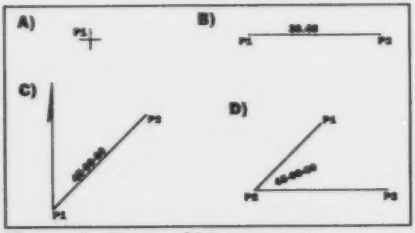

Figure 4 - Types of Measurements

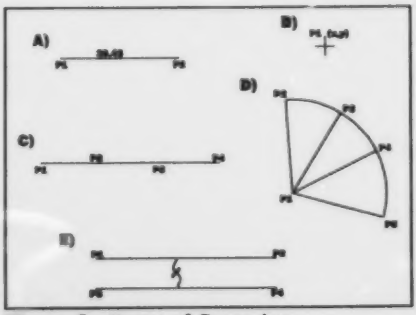

Figure 5 - Types of Constraints

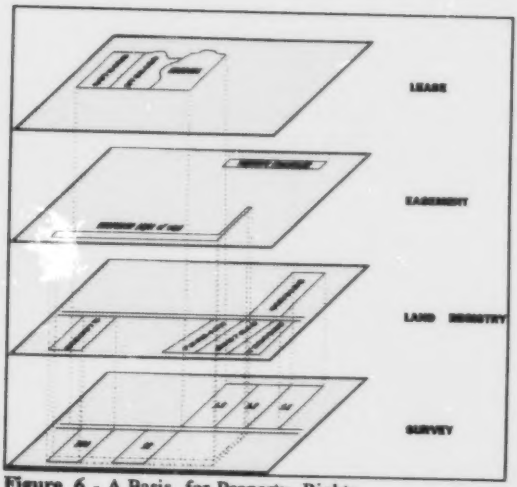

Figure 6 - A Basis for Property Rights

Standards of accuracy for digital soil resource data stored in the National Soils Data Base (NSDB)

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ABSTRACT

The Land Resource Research Centre is responsible for the development and implementation of standards for digital soil inventory maps stored in the NSDB. These developments required, among other things, the definition of standards relating to two aspects of map accuracy. The first standard defines the fidelity with which the digital data represents the manuscript lines. It represents the development of a digital standard to replace a publication "cartographic" standard. The second involves measuring and documenting the positional accuracy of the map with respect to the earth's surface. It represents a new standard which was not part of the published product but is required to define the expected precision with which these data can be combined with data from other sources. (In published maps, the soil thematic boundaries were registered to base map information). In absolute terms, both of these standards are dependent on the scale of the original manuscript.

This presentation documents a project in LRRC to adapt and develop appropriate standards of accuracy for digital soil maps. It defines the standards which apply to data in the National Soils Data Base (NSDB).

Le Centre de recherche sur les terres (CRT) est responsable pour le développement et la réalisation des normes pour les cartes d'inventaire de sols numérizées et emmagasinées dans le BNDS. Entre autre, ces développements ont exigé la définition des normes concernant deux aspects de précision des cartes.

La première des normes décrit la fidélité avec laquelle les données numérizées représentent les lignes sur la carte manuscrite. Elle représente le développement d'une norme numérizée pour remplacer une norme de publication "cartographique". La deuxième s'occupe de la délimitation et documentation de la position actuelle des endroits sur la carte en comparaison avec l'endroit sur la surface de la terre. Elle représente une

norme nouvelle qui ne fait pas partie de la carte imprimée mais qui est nécessaire pour localizer exactement les sols et autres attributs quand les données sont combinées avec d'autres types de données. (Pour les cartes publiées, les limites de sols étaient reliées à la carte de base). En termes absolue, les deux normes dépendent de l'échelle du manuscrit original.

Cette présentation donne les résultats d'un projet du CRT qui a adapté et a développé les normes de précision juste pour les cartes de sols numérizées. En réalité ils sont les normes qui s'appliquent aux données de la banque nationale des données de sols (BNDS).

INTRODUCTION

One of the concerns of cartographers over the past few years as the technology of map production has moved from traditional manual techniques to automated and computer assisted procedures is the preservation of cartographic quality in the resultant digital representation of the map. This topic relates to many other aspects of digital cartography including processes of generalization, application of the data at different scales, registration of data from divergent sources etc. In addition to these considerations which are primarily concerns of a traditional cartographic nature there are the considerations related to the new technology. The digital data are being used increasingly for research and analysis. In these applications it is important that the data are well organized and can be manipulated with speed. As this aspect becomes more important, and as the analysis is transferred from mainframe computers to mini and microcomputers and as the number of layers of data to be processed simultaneously increases there is an increasing conflict between the data quantity and structure which is ideal for analysis and the data quantity and structure which is ideal for cartographic representation.

Within the National Soil Data Base (NSDB), considerations include questions of (i) data capture specifications to ensure adequate data to represent the level of detail contained on the manuscript, (ii) specifications for generalization procedures to eliminate excessive quantities of data while retaining sufficient information for precision, (iii) the geographic edit to verify and document the positional accuracy of the data with respect to the earth's surface, (iv) conditions of minimum size (and/or dimensions) for areas to be represented in digital form, (v) definition of scales over which the data can be used.

Wosten et al (1987) discuss of data quantity associated with soil inventory information from the aspect of cost effectiveness and accuracy required. Nickerson (1988) and McMaster (1987) outline some of the considerations from the standpoint of map generalization. These aspects are, in reality, opposite aspects of the scale consideration. Reference to geographic edit accuracy and source.

It is the purpose of this research to establish the basic principals of operation of the NSDB to define the standards for the preservation of cartographic quality in the digital representation of soil inventory map data.

THEORETICAL CONSIDERATIONS

The fidelity of digital data representation of the manuscript lines.

Basic Assumptions:

1. Computer generated plotted maps will normally have a line width of 0.5 mm.
2. Quality specifications require that the digital representation must fall within one line width (0.5 mm) of the manuscript. This represents a cartographic/artistic visual criteria rather than a mathematical or technical one.
3. The narrowest dimension which can be represented will therefore be 2 line widths of 1.0 mm. This implies that the minimum arc will be defined by a circle of radius 0.5 mm.

These assumptions are represented in figure 1.

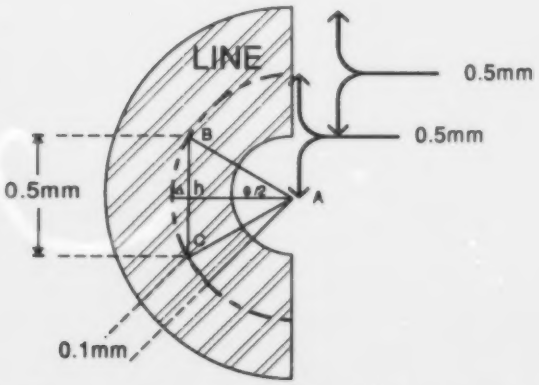

Figure 1: Schematic representation of the smallest detail to be represented.

If data coordinates are located at a maximum displacement of 0.5 mm, the maximum discrepancy between the digital representation and the manuscript occurs at the midpoint of the base of triangle ABC. For this case, the following calculations apply:

the height of the triangle 'h' can be determined as

$$h = r(\cos\theta/2) \qquad \ldots.1,$$

the length of the line displacement, L_Δ, is then given by the equation

$$L_\Delta = r(1 - \cos\theta/2) \qquad \ldots.2.$$

Minimum area considerations:

From a practical standpoint, it was decided that the minimum soil area which would be represented on a map or in the corresponding digital format would be 0.25 cm^2 on the map manuscript (i.e. corresponding to a square 0.5 cm on the side). Within the digital representation, it was felt that the maximum allowable error (theoretical) introduced by reducing the number of data points used to represent a line should be no greater than 10 % of this value or 0.025 cm^2. Again, with reference to figure 1, the area of the sector of the circle is given by the formula

$$A_s = r^2\theta/2 \qquad ....3,$$

and the area of the triangle is given by

$$A_T = b.h/2$$
$$= r^2(\sin\theta/2.\cos\theta/2) \quad ....4.$$

The error introduced through the representation of the area by triangle ABC rather than the sector of a circle is

$$A_\Delta = A_s - A_T$$
$$= r^2(\theta/2 - \sin\theta/2.\cos\theta/2) \quad ...5.$$

Equations 2 and 5 were used to calculate the linear displacement and errors in area as the map scale was enlarged up to 16 times. The results of these calculations are summarized in Table 1. This simple analysis suggests that, based on linear displacement errors and area errors, data which meet the criteria established for maximum distance between coordinates can be scaled up by a factor of 4 and still be within the maximum allowable tolerances of area and length.

Table 1: Linear displacement and area errors as a function of map scales (All units are based on map manuscript measurements)

Radius r (mm)	Relative Map Scale	Linear displacement L_Δ (mm)	Area error A_Δ (mm^2)	Cartographic (visual) Acceptability
0.5	1	0.670	0.1142	Unacceptable
1.0	2	0.134	0.4566	"
2.0	4	0.268	1.8264	"
4.0	8	0.536	7.3058	"
8.0	16	1.072	29.2231	"

PRACTICAL APPLICATION

The conditions specified in the theoretical considerations were created in practice using an ARC/Info GIS. A circle of radius 0.5 was generated using the system capabilities and then the volume of data reduced by specifying a "weeding" tolerance of 0.5. The resultant figure is quite similar to the theory, figure 2. The main difference reflects the fact that the software inserts a node every 500 vertices and this causes some distortion from the

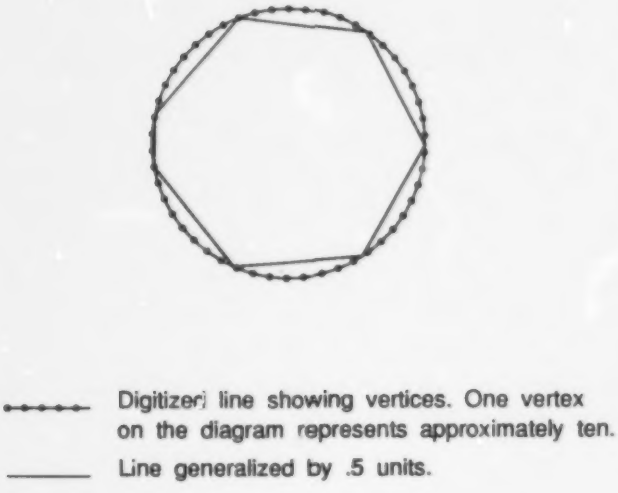

Figure 2: Graphical representation of the digital data used to test the theory.

theoretical figure. These results were sufficiently close to the calculated values that the same criteria were applied to a standard soil map.

The map was digitized using a Gentian Hi-State digitizing table with a precision specification of 0.003 inches. The data were collected in stream digitizing mode at a rate of 10 points per second. Experience has shown that a skilled operator using this system will capture the complete cartographic detail from the map manuscript.

The map was cleaned by the ARC/Info software and a verification plot was compared to the manuscript for accuracy of the digital data. Throughout the map the digital representation was well within the criteria of one line width (0.5 mm) of the map manuscript.

The digital data were then generalized by the ARC/Info software routine "GENERALIZE" to a tolerance of 0.5 mm and plotted. When the generalized plot was compared to the map manuscript the criteria of precision and fidelity were NOT MET. The generalized map was reviewed by a committee of four professional cartographers and assessed to be unacceptable from a visual cartographic standpoint. The committee considered how faithfully the map coincided with the manuscript and also evaluated the smoothness of the lines and the absence of obvious vertices connected by straight lines to represent a curved line. The generalized plot failed to meet the cartographic requirements of this second criteria.

An empirical trial was carried out to establish the largest generalizing tolerance which would still meet the requirements for cartographic quality. Copies of the original data were generalized to of 0.4, 0.3, 0.2, and 0.1 mm. When these were examined by the cartographers they determined that 0.2 mm was the largest generalizing tolerance which could be used if a cartographic quality plot was required. In practical terms, this criterion represents a location accuracy of ±10 meters on the ground at a map scale of 1:50,000.

For thematic information such as soil map, this level of spatial resolution is much greater than the precision of the soil boundaries. However, where the soil boundaries coincide with other landscape features (e.g. shoreline, scarp) this level of precision provides a measure of confidence especially when the soil data are combined with data from other sources. Furthermore, as part of the data validation process, the locations of several clearly identifiable features on the soil map are compared to their location on National Topographic maps. This 'geographic edit' provides a measure of positional accuracy of the map. A maximum error in position of 1.0 mm on the manuscript has been established for positional accuracy of maps in the NSDB. The actual displacement of the test points from the reference points is documented in the metadata of the digital soil map.

It is important for the principal users of soil maps (the farmers, agriculturalists, and land use planners) to have confidence in the information on the soil map. In practice, lines of cartographic quality which show smooth delineations of different soil areas which reflect the farmer's understanding of his land and positional accuracy of known geographic features provide the necessary reassurance of the quality of the data.

For purposes of analysis, where the soil map is combined with spatial data from other sources, it is convenient when the common boundaries (e.g. shorelines) are closely aligned. It must be recognized that when the data are used over a wide range of scales the larger scale data will normally carry much more detail in the boundary lines.

DISCUSSION AND CONCLUSIONS

In general terms, the visual rating was dramatically more rigorous than the mathematical criteria in assessing map fidelity. Clearly, if the data are reduced to standards which meet the requirement for cartographic quality, they will also meet requirements for analysis and interpretation. By this reasoning the data from soil maps should be appropriate for combination with other spatial data and analysis over a very wide range of scales. This apparent result is quite misleading because of the nature of soil maps and the way the data are collected. The soils mapped at a specific scale are grouped into units which are appropriate to that level of generalization. At larger scales the kinds of soil areas delineated change to reflect additional properties which can be shown on larger scale maps. In addition, the precision with which the properties can be characterized increases with increasing map scale. While a smaller scale soil map may contain the parameters required for analysis and interpretation at a larger scale, the data

may not be sufficiently accurate (in location) or precise (class limits are too broad) to meet the needs of the interpretation. It is very important for the user to understand the content and limitations of data on a soil map especially when these data in a GIS environment.

The reduction of data to the standards established for the NSDB allows for improved efficiency as the volume of data to store and manipulate is minimized. The limits for data reduction are determined by cartographic (visual) criteria rather than mathematical or analytical ones. While these standards provide data which provide the user with confidence in the fidelity with which the author's manuscript is represented and a measure of the positional accuracy to be expected, they may also lead to a false sense of assurance when the data are used for analysis at scales much larger than the intensity of data collection.

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ABSTRACT

Predicting Water Quality Using a Combined Non-Point Source Model and GIS

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Watersned hydrologic-water quality models are receiving widespread application in the development of remedial action plans for non-point source runoff management. The HSPF (Hydrologic Simulation Program for Fortran) program, supported by the U.S. Environmental Protection Agency, has been applied to developing best management practices (BMP's) for a planned "environmentally sustainable" high density residential development and to assessing the environmental benefits of conservation farming practices.

HSPF uses landscape units termed Pervious Land Segments (PLS) with homogeneous soil, topographic slope and land use attributes as principle computational units. Dynamic runoff simulations have been performed to predict event-based storm runoff, erosion and receiving water quality under several management scenarios.

PLS unit definition was greatly facilitated by a GIS approach, in which the soil, slope and landuse layers were analytically overlayed to create a new unique PLS unit map, with combined attributes. Using GIS, this process was iteratively performed to arrive at the desired number and density of PLS units.

The GIS was also used for the display of predicted data for each PLS, and led to spatial analyses of temporal data which originate from tabular model output data. Furthermore, subsequent analyses of the yield data was performed with independent variables to identify priority areas and BMP's.

Prévision de la qualité de l'eau à l'aide d'un modèle non ponctuel et d'un SIG combiné

RÉSUMÉ

Les modèles sur la qualité de l'eau - l'hydrologie des bassins versants trouvent de plus en plus d'applications lors de l'élaboration de plans de mesures correctrices destinés à la gestion des eaux de ruissellement non ponctuel. On a eu recours au programme HSPF (programme de modélisation hydrologique en Fortran) de l'Agence américaine de protection de l'environnement pour élaborer les meilleures pratiques de gestion de projets domiciliaires à forte densité "viables sur le plan environnemental" et évaluer les avantages environnementaux des pratiques agricoles de conservation.

Le programme HSPF fait appel à des unités de paysage qu'il appelle unités territoriales accessibles et dont les attributs d'utilisation des terres, de pente et de sols sont homogènes et servent d'unités de calcul de principe. Des simulations dynamiques du ruissellement ont été effectuées afin de prédire l'écoulement d'averses, l'érosion et la qualité de l'eau réceptrice lors d'événements particuliers dans le cadre de plusieurs scénarios de gestion.

L'utilisation d'un SIG a beaucoup facilité la définition des unités territoriales accessibles; les couches de données sur l'utilisation des terres, la pente et les sols ont pu être superposées de façon analytique pour obtenir une nouvelle carte unique des unités territoriales accessibles présentant les attributs combinés. Grâce au SIG, ce processus a été effectué par itération afin d'obtenir le nombre et la densité souhaités des unités territoriales accessibles.

Le SIG a également permis d'afficher les données prévues pour chaque unité territoriale accessible ainsi que des analyses spatiales des données temporelles provenant des données sous forme de tableau produites par le modèle. De plus, des analyses ultérieures des données ainsi obtenues ont été effectuées à l'aide de variables indépendantes afin d'identifier les secteurs prioritaires et les meilleures pratiques de gestion.

SIRS pour la récolte forestière : outil d'inventaire ou moyen de planification ?

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Résumé: En foresterie, la récolte des bois doit respecter l'encadrement visuel des sites voués à la récréation et la conservation. Pour atteindre cet objectif, il s'agit de choisir adéquatement les lieux (les peuplements forestiers) et les moments (les périodes de coupes) où les interventions seront réalisées sur le territoire. Satisfaire à la fois les besoins de l'industrie forestière et les exigences de qualité de paysage nécessite un processus de prise de décision complexe. Les fonctionnalités actuelles ne sont pas suffisantes et il faudrait faire évoluer les GIS existants vers de véritables SDSS.

À partir de cette réflexion initiale, cet article décrit une méthode de prise de décision basée sur la simulation et identifie les nouvelles caractéristiques que devront avoir les GIS pour répondre aux besoins de la planification.

SIS for wood harvesting : inventory tool or planning tool ?

Abstract: In forestry, wood harvesting must respect the visual environment of sites devoted to recreation and preservation. To achieve this goal, one must choose the appropriate location (forest stands) and time (logging periods) to execute the logging operations. To satisfy both the forest industry needs and the landscape quality requirements, a complex decision-making process must be followed. The actual tools are not sufficient and the existing GIS's must evolve toward a true DSS.

Starting from that initial acknowledgement, this paper describes a decision-making method based on simulation and identifies the new characteristics that a GIS must have in order to meet the planning needs of an organisation.

1. Introduction

Quel que soit le domaine considéré, la diversité des ressources disponibles et les besoins multiples des utilisateurs conduiront à envisager plusieurs voies de développement. Mais un processus de prise de décision requiert comme préalable la définition des orientations de développement, et d'objectifs stratégiques qui tiennent compte de cette diversité. La planification qui découle de la stratégie empruntée comporte ainsi plusieurs options, parmi lesquelles le décideur devra choisir la meilleure en fonction de ses *critères d'évaluation*.

Dans ce contexte, le rôle des SIRS actuel est le plus souvent limité à reproduire les fonctionnalités d'une bonne cartographie exploitée par un spécialiste compétent; les améliorations résident essentiellement dans la *rapidité* et la *répétabilité des fonctions d'analyse*, la capacité (sous certaines conditions) de *maîtriser et d'accéder aisément à de grands volumes de données* et la *souplesse des représentations*.

Mais rien dans les logiciels actuels n'est conçu *spécifiquement* pour assister un décideur dans la définition de ses objectifs, dans leur traduction sous la forme de diverse variantes d'actions, dans l'évaluation de leurs avantages et inconvénients, et dans la sélection de la solution jugée optimale.

2. SIRS en tant qu'outil d'inventaire

2.1 Objectif d'un SIRS

Les SIRS conventionnels ont été conçus pour *gérer les données* qui décrivent le territoire. Après avoir réalisé l'inventaire des objets qui le composent selon le modèle qu'on s'en est fait, on est en mesure de décrire l'état du territoire au moment de l'inventaire.

Dans cette perspective, l'utilisation des SIRS tire en particulier profit des fonctionnalités d'analyse des données, pour acquérir une meilleure connaissance du territoire. Les informations obtenues aideront les utilisateurs et bénéficiaires à prendre des décisions concernant la *gestion du territoire* proprement dit; ce type d'utilisation des SIRS contribue le plus souvent à la prise de décisions ponctuelles, situées à un niveau dit *opérationnel*. Il serait cependant souhaitable qu'un SIRS puisse aussi assister une prise de décision située plus haut dans la pyramide de décision, et permettre ainsi une traduction des objectifs généraux de l'organisation en opérations détaillées.

2.2 État du territoire et de ses objets

2.2.1 Inventaire d'objets

Un territoire est considéré comme un ensemble d'**objets**, possédant chacun certaines *caractéristiques*. L'information utilisée pour décrire le territoire peut être de différentes natures, par exemple: images satellites, banques de données, photographies aériennes, cartes du territoire. Selon l'objectif poursuivi, la description du territoire sera plus ou moins complexe. On peut considérer les objets individuellement ou collectivement, par groupe d'objets distincts ou par population.

2.2.2 Propriétés descriptives et spatiales

Un *objet* peut être décrit individuellement par des **propriétés descriptives** et des **composantes spatiales**. Les *propriétés descriptives* représentent les caractéristiques que le décideur attribue à l'objet pour le décrire compte tenu de son existence dans le monde réel et des objectifs qu'il poursuit. Les

composantes spatiales permettent la description de l'objet dans l'espace quant à sa position, son orientation, sa forme et sa taille (Chevallier, Bédard 1991).

2.2.3 Groupe d'objets et relations spatiales

Un objet peut aussi être situé par rapport à un autre objet ou à un groupe d'objets. On identifie alors les **relations**, *descriptives ou spatiales*, que cet objet a avec les autres. Par exemple, un objet peut, d'une part, avoir un ordre dans un groupe, et d'autre part, être contigü, inclu en partie ou en totalité dans un autre (Champoux 1991).

2.2.4 Population et distribution spatiale

Un ensemble d'objets possédant des caractéristiques communes peuvent former une **population**. Cette population possède, en plus des propriétés spatiales des objets considérés individuellement, des attributs qui permettent de décrire sa distribution spatiale sur le territoire (Bilodeau 1991).

2.2.5 Définition restreinte d'un état

En tenant compte des particularités mentionnées plus haut, on peut définir l'état d'un territoire par trois aspects :

- l'ensemble des *caractéristiques descriptives et spatiales* des objets qui le composent; l'état du territoire est alors défini par l'ensemble des valeurs d'attribut de tous les objets existants;
- l'ensemble des *relations descriptives et spatiales* entre deux objets;
- l'ensemble des *distributions descriptives et spatiales* de l'ensemble des objets ou de la population.

Il convient de remarquer que cette définition ne comporte pas d'élément temporel. On ne considère que l'état instantané sans faire référence au présent, au passé ou au futur.

2.3 Historique et possibilités d'extrapolation

Il est possible de conserver dans un SIRS certaines données historiques, décrivant l'évolution passée des objets. Les formes et techniques utilisées pour gérer cet historique peuvent être diverses, mais il n'y a pas lieu de les analyser ici plus en détail.

Sur la base d'un historique, on peut dans certains cas "prévoir l'avenir", plus précisément extrapoler sur une période à venir l'évolution de certains des phénomènes décrits dans le SIRS (Lowell 1989, 1991). Ceci pourra être envisagé dans la mesure où :

- la nature des phénomènes le permet (par exemple: la croissance d'une population forestière);
- on fait l'hypothèse que les conditions influençant cette évolution ne changeront pas de manière significative;
- la durée d'extrapolation est "relativement limitée".

On peut remarquer que de telles fonctions d'extrapolation ne font généralement pas partie d'un SIRS, mais constituent le plus souvent des applications indépendantes utilisant les données d'un "SIRS - inventaire".

3. Notion de prise de décision

3.1 Que veut dire *décider* en matière de gestion du territoire ?

En gestion du territoire, **décider** peut être défini comme "choisir l'action la plus adéquate à réaliser sur le territoire pour atteindre un objectif fixé". Le processus décisionnel comporte donc trois éléments de base:

- le *territoire* sur lequel l'action envisagée exercera son effet;
- l'*action* elle-même;
- le *décideur* qui choisit l'action désirée.

Du point de vue du décideur, il est nécessaire d'évaluer l'impact de l'action ou des actions envisagées. Cette évaluation peut porter :

- soit sur *l'action elle-même;*
- soit sur *l'effet* produit par l'action.

L'évaluation de l'*action* considérée isolément aura pour but de s'assurer qu'elle concourt bien aux objectifs fixés, et qu'elle est conçue selon les règles de l'art; c'est l'évaluation que tout spécialiste fait en permanence au long de son activité.

L'évaluation de l'*effet d'une action ou d'un ensemble d'actions*, par contre, permet de prendre en considération d'autres facteurs, et notamment :

(a) elle permet de considérer la *contribution globale d'un tel ensemble d'actions* aux objectifs;
(b) elle permet aussi - et surtout, en ce qui nous concerne ici - d'évaluer *l'impact d'une ou plusieurs actions sur l'environnement des objets* (au sens systémique du terme) sur lesquels on agit, ou de *considérer l'impact* des actions envisagées d'un *point de vue différent.*

Dans ce dernier cas, l'évaluation porte en fait sur la *comparaison des états du territoire avant et après l'action*, considérés si besoin est selon différents points de vue.

Ainsi, l'évaluation d'un plan de coupe forestière peut être évalué :

- en fonction de sa production en termes de volume produit et de coût (but *a* ci-dessus);
- en fonction de son impact sur l'érosion des sol ou sur la qualité du paysage (but *b* ci-dessus).

Par ailleurs, dans la perspective d'une planification complexe de travaux comportant plusieurs étapes, l'évaluation devrait être faite à *court, moyen* et *long* terme.

Le choix de "l'action adéquate" repose donc sur un processus décisionnel comportant trois parties :

- la *simulation* de l'action;
- l'*extrapolation* des états futurs à court, moyen et long terme;
- l'*évaluation globale* de l'impact de l'action à court, moyen et long terme.

Le SIRS sur lequel se base le processus décisionnel doit permette la gestion des données nécessaires au choix de l'action optimale. Pour pouvoir évaluer l'impact d'une action, le décideur doit être en possession des états qui font l'objet de l'évaluation. En d'autre termes, pour mieux contribuer à une prise de décision, un SIRS devrait permettre de conserver et de gérer les multiples états résultant des différents développements simulés du territoire, au lieu de gérer un inventaire unique décrivant un seul état du territoire.

Dans le cas où un état peut résulter d'une *série d'actions échelonnées dans le temps*, le décideur doit être en mesure de pouvoir construire ou retracer le cheminement conduisant à l'état final. Pour faciliter la description de variantes, la structure du système permettra ainsi de modifier un plan d'action à partir d'un certain stade, sans être obliger de tout recommencer. Il est donc important de pouvoir garder en mémoire les transactions intermédiaires, c'est-à-dire conserver la trace des traitements qui ont conduit aux états évalués.

De même, les effets de certaines actions dépendent du résultat des actions antérieures : il faut donc en conserver également la trace.

3.2 Changements d'état

3.2.1 Modification d'un objet dans le temps

Jusqu'à maintenant, on n'a considéré dans un SIRS que l'état instantané d'un objet, celui qui existe à un moment donné (exception faite de l'*historique* évoqué à la section 2.3 ci-dessus). Lorsqu'on considère la dimension temporelle, il est possible de constater le changement d'état d'un objet, c'est-à-dire la modification dans le temps de la valeur d'une de ses propriétés descriptives ou de ses composantes spatiales (Gagnon 1992).

Sur un axe de déroulement le long duquel se succèdent en alternance états et changements, on définira un **chaînon de changement** comme l'ensemble constitué de (cf figure 1) :

- l'état initial d'un objet défini arbitrairement;
- le changement qui modifie l'objet;
- l'état final résultant du changement.

Si on considère une succession de chaînons constituant une planification complexe, l'état final d'un chaînon donné correspond à l'état initial du chaînon suivant. Là où un inventaire pouvait être représenté par une photographie instantanée d'un lieu donné, un axe de déroulement peut être vu comme un ensemble ordonné de photographies prises en des moments différents (de même que lorsqu'on maintient l'historique d'un système d'information, on mémorise une succession d'états du territoire).

3.2.2 Facteurs de changement *endogènes* et *exogènes*

Dans le contexte du développement du territoire, l'homme intervient sur le milieu en planifiant ses actions dans le but d'atteindre les objectifs de développement. Dans cette perspective, un objet peut être modifié par deux types de facteurs :

- d'une part, les facteurs qui regroupent les actions prévues, soit les **facteurs endogènes** à la planification;
- d'autre part, les facteurs qui ne font pas partie de la planification, soit les **facteurs exogènes** à la planification.

Les *facteurs endogènes* regroupent toute intervention humaine planifiée, par exemple : travaux de remblais-déblais, coupe forestière, construction de routes.

Les *facteurs exogènes* se distinguent selon trois classes: les interventions humaines qui n'ont pas été prévues dans le cadre de la planification, les paramètres d'évolution spontanée prévisible qui correspondent à l'évolution naturelle (telle la croissance végétale), et les événements naturels imprévisibles (comme les incendies forestières ou les inondations).

Dans le cadre du présent rapport, on ne tiendra compte que des interventions humaines planifiées et des paramètres d'évolution naturelle prévisible; on considérera qu'un état peut être (a) le résultat de la seule évolution naturelle prévisible ou (b) le résultat de l'évolution naturelle prévisible combinée à une intervention humaine planifiée. On n'abordera pas l'étude probabiliste de la localisation des événements naturels dits imprévisibles mais dont l'avènement est statistiquement prévisible, telles les épidémies de ravageurs forestiers, ni de l'effet de ce type d'événement sur la planification des interventions.

3.2.3 Action, groupe d'actions et programme d'actions

Les interventions humaines peuvent être classifiées de manière hiérarchique.

Au niveau le plus élémentaire, l'action est le composant de base: sa description comporte la description explicite de son impact sur un objet du territoire.

A un niveau plus général, on définit un groupe d'actions comme étant un *ensemble d'actions corrélées qui s'effectuent en une période de temps déterminée*. Le groupe d'actions agit comme un tout sur l'état d'un ensemble d'objets. Dans l'optique de la planification, les actions qui composent un groupe d'actions sont considérées comme *simultanées*. Par exemple, un plan annuel d'interventions forestières, qui se compose d'un ensemble d'actions individuelles, modifie un ensemble de cellules forestières.

Lorsqu'on considère un horizon de planification donné, l'ensemble des groupes d'actions porte le nom de programme. Un programme est une *suite ordonnée des groupes d'actions*. Chaque groupe d'actions correspond alors à une étape du programme, au sens courant du terme (cf figure 2).

3.3 Planification des changements

3.3.1 Série de futurs possibles

A partir d'un état initial du territoire, si on considère une action possible, deux options peuvent être envisagées :

- il y aura action;
- aucune action n'est prévue.

La prise de décision conduit donc au choix entre *deux chaînons potentiels divergents*. Si on poursuit la planification dans une seconde étape, la même situation se présente et il en résulterait quatre états finaux.

De manière générale, le choix possible à un moment donné entre n actions génère donc n+1 *chaînons potentiels divergents* (cf figure 3). Chaque suite de chaînons aboutissant à un état final constitue un programme d'actions particulier et génère une ligne de futur potentiel distincte. L'ensemble de ces programmes d'action potentiels définit *l'espace de solution d'un problème de planification donné*.

Un cas particulier vaut la peine d'être souligner. Il est possible que dans le cadre d'un projet donné, l'état *final* visé soit fixé à l'avance. Même dans ce cas, l'existence de plusieurs chemins évolutifs possibles pour y arriver correspondra à des programmes d'actions différents.

3.3.2 Évaluation des changements

La planification porte sur des actions. Cependant le choix du décideur s'appuie sur l'évaluation des états. On planifie des programmes de coupes forestières en regard des résultats que ces coupes produiront. Donc, l'intérêt de la planification n'est pas tant dans les actions elles-même que dans l'impact qu'elles auront (cf figure 4).

L'évaluation des états résultants est donc indispensable pour la prise de décision. Le processus d'évaluation utilisera différents critères en fonction de l'impact qu'on veut mesurer. Les bases d'évaluation peuvent revêtir différentes formes, telles des images thématiques, des rapports, des cartes, etc., qu'on appelle des vues. On définit un scénario comme étant la série de vues correspondant au programme d'actions. A chaque étape intermédiaire de la planification, un état sera généré et une vue y sera associée. Ce sera à l'aide de ces vues que le décideur effectuera son choix quant au programme d'actions à réaliser.

4. SIRS en tant qu'aide à la décision

4.1 Structure de données

Afin de faire évoluer les SIRS actuels vers de véritables Systèmes d'Aide à la Décision à Référence Spatiale, les données descriptives de certaines composantes du processus décisionnel doivent être incluses dans la structure de données. Ces nouveaux éléments sont nommés ici **primitives décisionnelles** dans le même sens que les *primitives géométriques* dans les SIRS. Ces primitives décisionnelles correspondent aux composantes du processus de planification décrit plus haut. La figure 5 illustre la structure générale du modèle de données suggéré. Les cases ombrées correspondent aux facteurs exogènes non prévisibles mentionnés à la section 3.2.2 ci-dessus, et que nous négligerons dans le cadre d'un processus de type déterministe tel que celui suggéré.

Quel que soit le SIRS considéré, ces nouvelles composantes sont des données qui devront être intégrées à la structure de données actuelle du SIRS, et en constitueront un sous-système. Les éléments qui font le lien commun entre ce sous-système et le reste du SIRS sont les "données d'inventaire" évoquées plus haut. Cependant, il est important de souligner que le sous-système de prise de décision n'agira pas directement sur les données de l'inventaire dit 'opérationnel' du SIRS. Pour des raison d'intégrité d'information, le sous-système de prise de décision utilisera *une copie des données d'inventaire*. Un lien devra indiquer l'appartenance d'un objet de l'inventaire courant au sous-système décisionnel compte tenu qu'il pourra être modifié ultérieurement au cours de la tenue à jour de l'inventaire.

4.1.1 Données descriptives et spatiales (module *descripti*)

La partie descriptive et spatiale regroupera l'ensemble des données d'inventaire qui seront générées par le processus de planification des actions. Ainsi, chaque état du territoire tel que défini plus haut sera mémorisé ici. De plus, pour pouvoir assurer la gestion simultanée de plusieurs "états futurs envisagés", les objets du territoire pourront être rattachés de façon indépendante à plusieurs états distincts.

4.1.2 Données liées à l'action *(module actif)*

Cette partie du sous-système contiendra la description de tout ce qui est susceptible de modifier les objets de l'inventaire. On y trouve les facteurs endogènes et exogènes à la planification (section 3.2.2). Parmi les facteurs endogènes, les données sont organisées selon la structure *programmes - groupes d'actions - actions*. Ici encore chacune de ces composantes sont indépendantes, de manière à laisser au décideur l'entière liberté dans la description de variantes. Ainsi, une action pourra appartenir à un ou plusieurs groupes d'actions; un groupe d'actions pourra appartenir à un ou plusieurs programmes d'actions.

4.1.3 Relations de changement d'état

Les modules "Descriptif" et "Actif" sont reliés entre eux par le fait le deuxième agit sur le premier. Les différents liens qui unissent leurs composantes se situent à deux niveaux et correspondent aux deux notions déjà vues plus haut :

- les chaînons de changement;
- les lignes de futurs possibles.

Au niveau le plus général, un état du territoire est rattachée à un programme puisque ce dernier génère toujours un état résultant. Au niveau le plus détaillé, la relation est définie entre les objets et les actions.

4.1.4 Données liées à la prise de décision (*module décisionnel*)

Le module "Décisionnel" comporte les éléments qui permettent d'évaluer l'impact des actions, puis de prendre la décision. Le module contient donc les *vues* représentant les états à évaluer d'une part et les *critères d'évaluation* qui seront appliqués aux vues, et permettront de juger de la pertinence de l'action ou du groupe d'actions envisagé.

Il existe deux classes de vue: les **vues à court terme** qui concernent l'état du territoire résultant directement de l'action) et les **visions futures** qui représentent les états futurs potentiels résultant de l'évolution en fonction des facteurs exogènes.

4.2 Processus de planification

L'information qui sera contenue dans le modèle de données décrit plus haut sera utilisée pour prendre une décision dans un contexte de planification, selon une démarche de planification appropriée (cf figure 6). Les éléments principaux de cette démarche sont en fait ceux qui entrent en jeu dans l'élaboration des bases de décision, soit

- les états futurs issus des programmes proposés;
- les états futurs issus de l'évolution spontannée;
- la production des vues correspondantes.

5. Conclusion

L'évolution des SIRS - que l'on a appelé ici "d'inventaire" pour les besoins de la démonstration - vers des Systèmes d'Aide à la Décision à Référence Spatiale nécessitera de multiples adaptations, tant au point de vue des logiciels, des données que de la méthode de travail des personnes concernées. Au-delà du simple progrès technologique, il nous apparaît comme évident que cette évolution est nécessaire, et qu'elle seule pourra justifier les énormes investissements consentis dans la cueillette des données.

Toutefois, les premières réflexions ci-dessus ne constituent qu'une esquisse, et ne font qu'effleurer l'immense champ de recherche qui permettra de rassembler au service des décideurs tous les moyens technologiques actuels (sans parler de ceux à venir ...). Dans ces recherches futures, il est vraisemblable que la prise en compte des facteurs humains et la contribution des sciences cognitives sera de première importance (Turk 1990) (Chevallier 1992)

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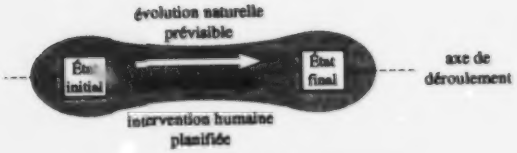

Figure 1 - Chaînon de changement

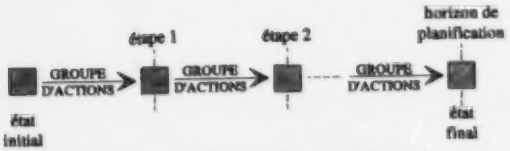

Figure 2 - Programme d'actions

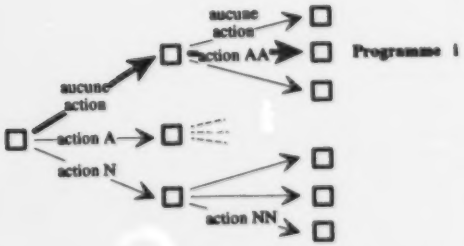

Figure 3 - Différentes lignes de futurs possibles

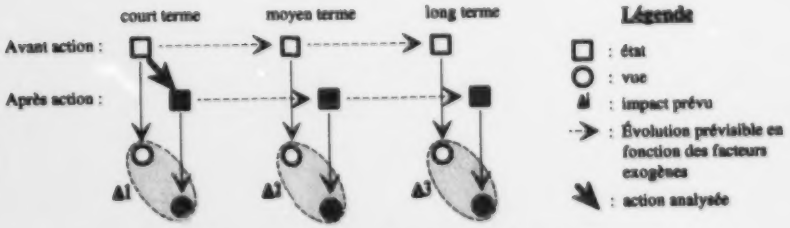

Figure 4 - Évaluation de l'impact d'une action donnée à court, moyen et long terme

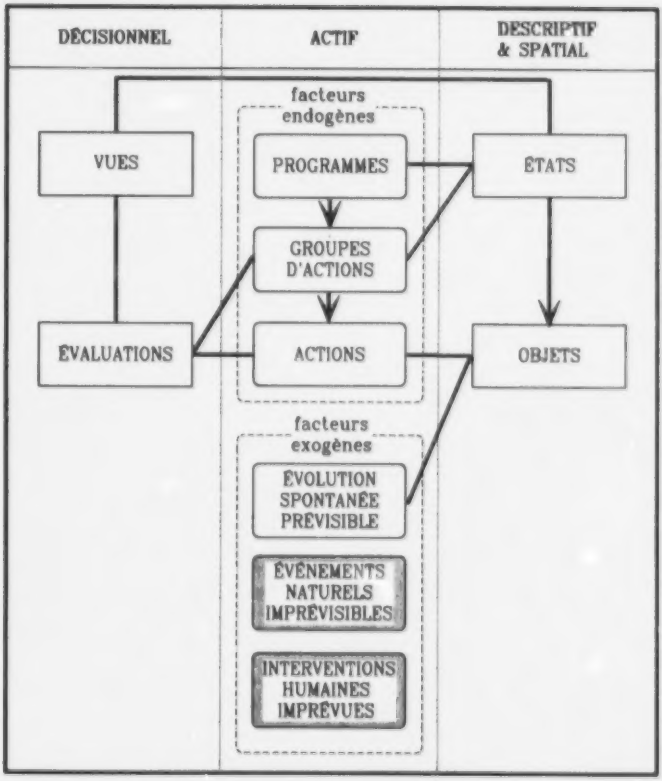

Figure 5 - Modèle de données supportant la prise de décision

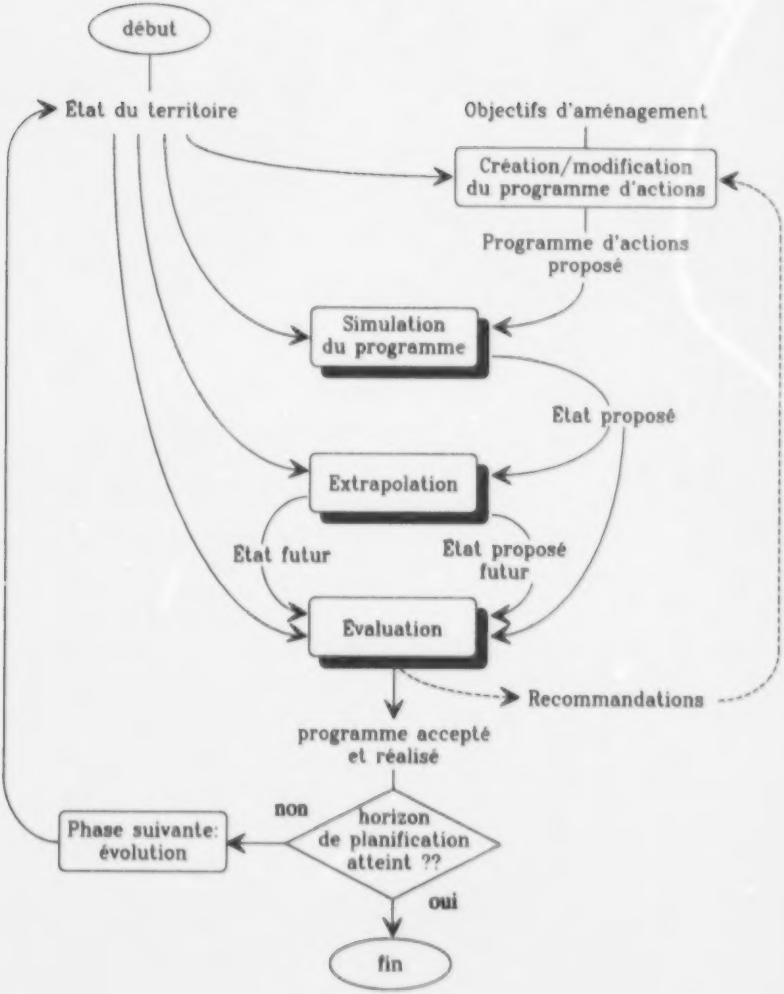

Figure 6 - Processus de prise de décision

ÉLÉMENTS DE GESTION POUR LES SUIVIS DE LA PLANIFICATION FORESTIÈRE AU QUÉBEC À L'AIDE DE GIS.

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Résumé

On doit optimiser l'utilisation du GIS pour parfaire nos connaissances de notre territoire forestier. Par l'implantation d'un modèle de suivi spatio-temporel forestier, on veut concevoir un outil de nature à encourager le gestionnaire à s'adapter avec le temps et aussi minimiser les effets de surprise lors de la réalisation des travaux. Actuellement, il y a peu d'intégration d'information dans le processus de planification de l'exploitation et de l'aménagement forestier. La gestion de ces informations est maintenant manipulable avec plus de souplesse. On doit identifier comment intégrer les impacts des interventions forestières sur l'écosystème forestier dans le processus décisionnel de planification. Pour mieux exploite: le potentiel d'un GIS, il faut emmagasiner les informations pertinentes au gestionnaire qui constituent la base de sa connaissance. En récoltant des informations sur les descriptions des opérations d'aménagement forestier, nous pouvons augmenter la précision de connaissance de la dynamique de la forêt.

MANAGEMENT ELEMENTS IN MONITORING FORESTRY PLANNING IN QUEBEC, WITH THE AID OF GIS

Abstract

The use of the GIS must be optimized to perfect our understanding of our forested land. The purpose in establishing a model for spatiotemporal forestry monitoring is to design a tool that will encourage managers to adapt over time, and to reduce surprises during operations to a minimum. There is currently very little integration of information in the planning process of forestry operations and development. Management of this information can now be handled with greater flexibility. We must determine how to integrate the impact of forestry operations on the forest ecosystem into the decision-making process in planning. To better realize the potential of a GIS, we must store the relevant information which constitutes a manager's knowledge base. By collecting information on the descriptions of forestry development operations, we can improve the precision of our knowledge of forest dynamics.

1. Introduction

Avec l'avancement d'une technologie telle que les GIS, nous en sommes arrivés à un point où il nous faut remettre en question des pratiques d'un autre âge. La capacité de gestion et d'interprétation des données forestières est maitenant une réalité plus facilement accessible.

Maintenant, il nous faut développer et intégrer une banque d'informations forestières portant sur l'ensemble des connaissances requises à la planification, au contrôle et au suivi des activités forestières. Ce problème est d'autant plus aigu que les ressources forestières de qualité se font plus rares et que la gestion de la forêt mélangée, comme c'est notre cas, est plus problématique.

Nous effectuons présentement notre planification stratégique et forestière avec une base de données qui correspondait à des informations du niveau tactique, c'est-à-dire, une réalité grossière de la réalité terrain. Nous allons tenter une expérience pour voir si l'on peut modifier nos méthodes de planification en ayant des informations plus exhaustives des travaux des années antérieures. Nous voulons concevoir un outil de guide de nature à encourager le gestionnaire à s'adapter avec le temps et ainsi minimiser les effets de surprise.

Pourquoi ne tenterions-nous pas de répartir les volumes par provenance pour obtenir un feedback des opérations versus les volumes de planification de ces mêmes secteurs. Ces données, considérées avec certains calculs de pondération, pourraient servir d'inventaire qui pourrait nous aider à préciser nos projections forestières. De plus, il faudrait conserver les données pour mieux modéliser les réactions des écosystèmes face aux différentes perturbations. Mais notre méthodologie actuelle de planification ne nous permet pas d'établir des procédures véritables de validation et de feedback.

Entre la planification et la réalisation des travaux sur le terrain, il y a un monde qu'il faut comprendre et où il y a beaucoup à retirer comme connaissance. Mais il faut savoir ce qu'on veut et comment ça va servir, cela pour éviter le phénomène du GIGO (garbage in, garbage out).

2. Les facteurs de gestion

Une des principales tâches qui incombe aux gestionnaires de la forêt est la surveillance de l'évolution de la forêt. Au Québec, nous utilisons le logiciel SYLVA comme outil de simulation du rendement des forêts. Il permet de définir les objectifs de rendement et l'envergure des travaux sylvicoles de chaque bénéficiaire de contrat d'aménagement. Mais les techniques actuelles rendent ardu ce processus. Il faut être en mesure d'obtenir un feedback sur la possibilité forestière (volume annuel à

récolter sans toucher au capital forestier) et sur tous les niveaux de la planification forestière.

Il faut protéger le peuplement commercial contre les essences indésirables pour assainir la forêt, maximiser son expansion et accélérer sa maturation par rapport au cycle de régénération naturelle. La stratégie actuelle de conservation des forêts tend vers cette optique tout en tenant compte d'un aménagement intégré qui considère toutes les ressources de la forêt. De plus, on veut s'efforcer de travailler avec la forêt en minimisant les interventions pour la remettre en production. On tend aussi vers l'élimination des interventions chimiques pour un plus grand respect de l'environnement.

Pour minimiser les pertes, nous devons protéger ses ressources contre les maladies, les invasions d'insectes et le feu. En connaissant tous les facteurs favorisant ces fléaux, nous devons prioriser ces zones susceptibles lors de nos planifications. Nous mettons nos efforts pour prévenir la tordeuse de bourgeon d'épinette. Enfin, pour s'assurer des approvisionnements de l'industrie, nous devons moduler les caractéristiques du peuplement en fonction de l'évolution future des besoins à desservir.

Tous ces points contribuent à promouvoir l'implantation d'un modèle pour un suivi spatio-temporel étudiant les relations de causes à effet.

La conception de ce modèle a été effectuée dans le contexte de l'approvisionnement d'usine de sciage et de déroulage. Nous évoluons avec la notion de rareté de la ressource. De plus, nos secteurs d'approvisionnement sont la zone de la forêt mélangée. Nous avions une tendance à aménager ces zones vers des vocations soit résineuses ou feuillues. Nous voulons maintenant respecter cet écosystème comme une entité différente, en lui redonnant sa vocation mixte. Mais cela ne se fait pas sans compliquer le travail d'aménologue forestier.

3. Les méthodologies de planification

Avant de géomatiser la planification forestière et instaurer un bon système de suivi spatio-temporel, il faut mettre les choses dans leur contexte et bien comprendre la dynamique de la planification forestière.

Au Québec, nous avons subdivisé la planification en trois étapes, d'abord le plan général de 25 ans, le plan quinquennal et la planification annuelle. Pour chacune de ces planifications, la base de données est celle fournie par le ministère des forêts du Québec (MFO) (cf. fig. 1). Chacune des étapes correspond à des niveaux décisionnel soit stratégique, tactique et opérationnel.

PLANIFICATION FORESTIERE
PLANIFICATION GÉNÉRALE STRATÉGIQUE
TERRITOIRE FORESTIER ALLOUÉ PAR LE CAAF (25 ANS)
CALCUL DE LA POSSIBILITÉ FORESTIERE
DÉTERMINATION DU VOLUME A RÉCOLTER PAR ESSENCE PAR ANNÉE
DÉTERMINATION DE LA SUPERFICIE MAXIMALE ANNUELLE RÉCOLTÉE
PLANIFICATION QUINQUENNALE TACTIQUE
RÉPARTITION TERRITORIALE EN 5 PLANS QUINQUENNAUX
DÉTERMINATION DES TERRITOIRES OPÉRATIONNELS
EN FONCTION DE LA POSSIBILITÉ FORESTIERE
EN FONCTION DE LA DISPONIBILITÉ DU VOLUME / TEMPS
EN FONCTION DE L'ÉTAT DU RÉSEAU ROUTIER ACTUEL
BASE DE DONNÉES (MFO)
CARTE FORESTIERE ÉCHELLE 1:20000
1:50000
-TABLE DE PEUPLEMENT
- TABLE DE REGROUPEMENT
-TABLE DE STOCK
-PLACETTE-ÉCHANTILLON
PLANIFICATION ANNUELLE OPÉRATIONNEL
COMPORTANT DES STRATES CONFORMES
AUX NORMES D'.INTERVENTION
A LA POSSIBILITÉ FORESTIERE ANNUELLE
AUX BESOINS DES BÉNIFICIAIRES DU CAAF
AU SEUIL DE RENTABILITÉ ÉCONOMIQUE
INVENTAIRE D'INTERVENTION
+
BASE DE DONNÉES DU SUIVI
SUIVI SPATIO-TEMPORELLE OPÉRATIONNEL
PROCESSUS DE MISE A JOUR
RAPPORTS ANNUELS
IMPACTS SUR LES PLANIFICATIONS
FEEDBACK SUR LA POSSIBILITÉ FORESTIERE
CONTRIBUTION A UNE MEILLEURE CONNAISSANCE DU TERRITOIRE

FIGURE 1

Le problème est que les données d'inventaires du MFO correspond à l'information du niveau stratégique et tactique. Elle ne convient pas du tout à l'information nécessaire au niveau opérationnel, c'est pourquoi le gestionnaire doit effectuer des inventaires d'intervention pour valider les informations avant de commencer la réalisation des travaux.

4. Le processus de la classification

La stratification

Il s'agit maintenant de segmenter la démarche du gestionnaire de la forêt pour arriver à une planification annuelle la plus près de la réalité. La base de tout ce système d'information est la fiabilité des données disponibles. On se doit donc de valider les informations provenant de la carte forestière par une vérification, par des points de contrôle sur le terrain. Puis, lorsqu'on a acquis confiance en la carte, nous pouvons passer à la phase de la classification des strates. Nous avons identifié quatre grandes classes de strates (cf. fig. 2).

1- Les strates inaccessibles

Dans la base de données du ministère des Forêts du Québec, on retrouve un critère d'accessibilité fourni par une classe de pente associée à chaque peuplement. Mais on doit aussi identifier les strates situées à des endroits inaccessibles de fait, soit: le plateau, les bas-fond et les peuplements isolés. Nous pouvons effectuer cette opération par une superposition des couches forestières et de courbes de niveau.

2- Les strates à prioriser

Ce sont des strates qui sont susceptibles d'encourir des pertes importantes de volumes si nous ne les récoltons pas à l'intérieur d'un délai donné. Il y a d'abord les régions qui viennent de subir des feux et des infectations d'insectes où il y a encore de la récupération possible. Puis, il faut agir à titre préventif en identifiant, sur le territoire, les strates répondant à des critères de vulnérabilité basés la composition en essences, l'âge et la densité du peuplement. Ultimement, il pourrait être utile de connaître le type de dépôt-drainage des strates. Il faudra alors intégrer les données éco-forestières pour connaître tous ces paramètres. Des travaux sont en cours au MFO pour classifier les critères de vulnérabilité et nous devrions connaître bientôt les résultats. On doit essayer de les intégrer, dans la mesure du possible, dans le cadre de notre planification.

3- Les strates en attente

- Les strates en régénération

  Ce sont les strates qui ont subi une perturbation (humaine et/ou naturelle) qui sont en voie de régénération en essences commerciales. Des travaux de reboisement ont pu y être effectués pour pallier à la régénération naturelle.

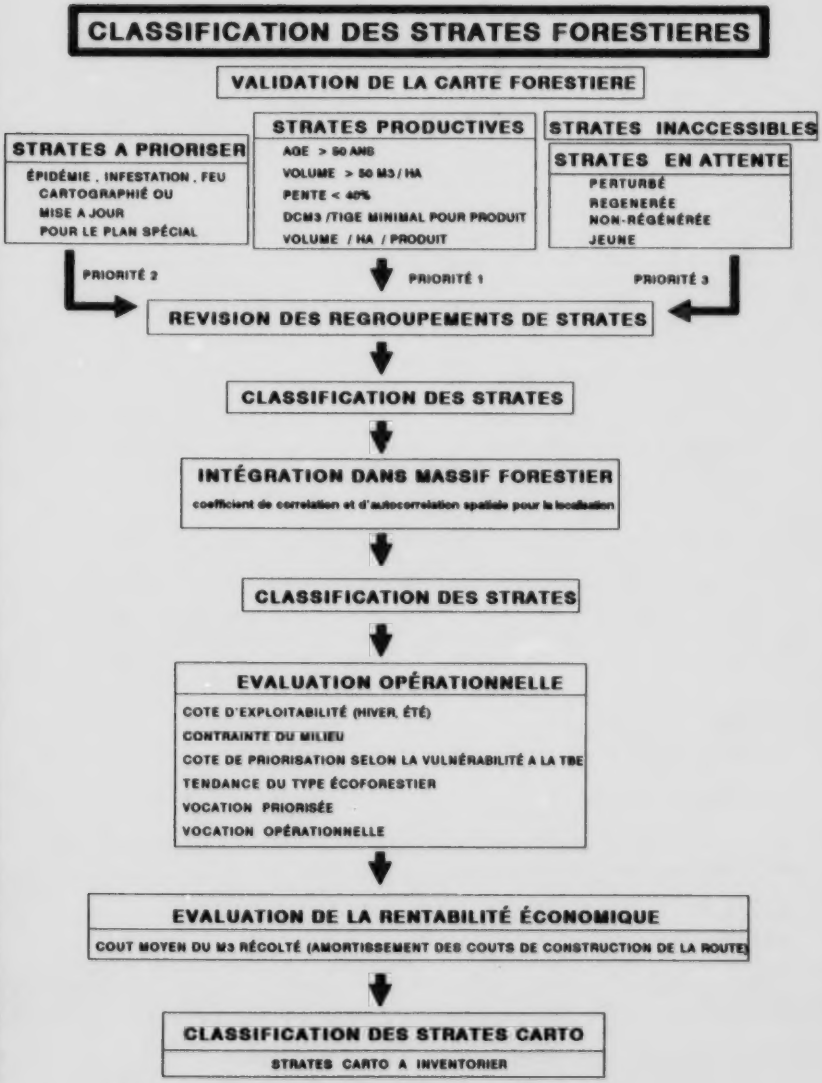
CLASSIFICATION DES STRATES FORESTIERES
VALIDATION DE LA CARTE FORESTIERE
STRATES A PRIORISER
ÉPIDÉMIE , INFESTATION , FEU
CARTOGRAPHIÉ OU
MISE A JOUR
POUR LE PLAN SPÉCIAL
STRATES PRODUCTIVES
AGE > 50 ANS
VOLUME > 50 M3 / HA
PENTE < 40%
DCM3 /TIGE MINIMAL POUR PRODUIT
VOLUME / HA / PRODUIT
STRATES INACCESSIBLES
STRATES EN ATTENTE
PERTURBÉ
REGENEREE
NON-RÉGÉNÉRÉE
JEUNE
PRIORITÉ 2
PRIORITÉ 1
PRIORITÉ 3
REVISION DES REGROUPEMENTS DE STRATES
CLASSIFICATION DES STRATES
INTÉGRATION DANS MASSIF FORESTIER
coefficient de correlation et d'autocorrelation spatiale pour la localisation
CLASSIFICATION DES STRATES
EVALUATION OPÉRATIONNELLE
COTE D'EXPLOITABILITÉ (HIVER, ÉTÉ)
CONTRAINTE DU MILIEU
COTE DE PRIORISATION SELON LA VULNÉRABILITÉ A LA TBE
TENDANCE DU TYPE ÉCOFORESTIER
VOCATION PRIORISÉE
VOCATION OPÉRATIONNELLE
EVALUATION DE LA RENTABILITÉ ÉCONOMIQUE
COUT MOYEN DU M3 RÉCOLTÉ (AMORTISSEMENT DES COUTS DE CONSTRUCTION DE LA ROUTE)
CLASSIFICATION DES STRATES CARTO
STRATES CARTO A INVENTORIER

FIGURE 2

- **Les strates jeunes**

  Ce sont les strates dont le volume et l'âge ne sont pas encore arrivés à leur optimum de développement. On leur donne une étiquette d'attente indiquant le nombre d'années en attente.

- **Les strates perturbées avec volume**

  Ce sont les strates qui ont subi une perturbation humaine et/ou naturelle par le passé et dont les paramètres actuels ne sont pas conformes à aucune norme d'intervention. Il se peut que si aucune intervention corrective est effectuée dans ces strates, elles risquent de mettre beaucoup de temps à recouvrer une productivité acceptable. Il est donc important de les examiner lorsqu'on exploite le territoire à proximité.

- **Les strates pertubée sans volume**

  Ce sont les strates qui ont subi des perturbations humaines et/ou naturelles et qui ne sont pas régénérées en essences commerciales. Il faut pouvoir les remettre en production éventuellement. Ces notes constituent habituellement le "back-log" qu'on doit remettre en production à grands frais.

Les strates en attente sont des entités qu'il faut prendre en considération pour que, lorsqu'on intervient dans un secteur, elles puissent être intégrées à la planification si possible. L'idéal serait que l'on passe le territoire au peigne fin pour aménager le territoire dans son entier. Mais, afin d'optimiser nos investissements, il est préférable de sélectionner les strates en attente où l'intervention appropriée les rendront disponibles à la récolte dans les périodes de pénurie. Aussi les choix, peuvent se fixer sur des critères écologiques fondés sur l'expérience pour des secteurs répondant bien aux interventions prescrites. Encore ici, on va chercher les couverts éco-forestiers et on compare l'historique à la planification. Encore faut-il avoir effectuer des suivis et garder ces données en historique.

4- Les strates productives

Ce sont les strates qui approvisionneront l'usine à court et à moyen terme Elles vont être le pivot de notre système.

Par la suite, nous devons réviser les regroupements des strates pour qu'elles répondent aux besoins du gestionnaire. La base de nos calculs étant l'échantillonnage, nous établissons nos critères discriminatoires sur ces résultats. Le ministère des Forêts a déjà effectué un regroupement. Nous devons revoir ces regroupements. La résultante de cette révision va se traduire en 7 classes:

1- les strates cartograghiques productives bien échantillonnées
2- les strates cartographiques productives mal échantillonnées
3- les strates cartographiques médiocres bien échantillonnées
4- les strates pertubés avec volumes

5- les strates perturbés sans volume mal régénérées
6- les strates jeunes
7- les strates en voie de régénération.

l'étape de stratification étant systématisée, on pourrait faciliter le travail du gestionnaire par l'intégration d'un système expert. Nous pensons que l'étape de la stratification en est une où on peut définir les mécanismes qui engendrent la certitude et ainsi dégager un formalisme de représentation de la connaissance et un mécanisme de déduction approprié.

L'expert utilise un ensemble de concepts opératoires où chacun d'entre eux correspond à un noeud de son heuristique. Nous avons peut-être tous les éléments en main pour systématiser cette étape sur la base d'un système expert. Mais, pour ce faire, il faut bâtir une base de données en laquelle on peut avoir confiance.

5. Intégration dans les massifs forestiers

Ensuite commence un travail où la technologie GIS peut se développer pour servir d'aide au repérage de massifs forestiers qui sont les blocs d'intervention de récolte. Les strates que l'on recherche se retrouvent dispersées sur notre territoire. Avec l'aide d'un coefficient de corrélation et d'autocorrélation spatiale, nous pourrions déterminer en divisant notre secteur selon la méthode du Quad-Tree, quels sont les secteurs où les phénomènes ont tendance à se regrouper le plus. (cf. fig.3). Au lieu de mettre des critères de contiguité, on pourrait plutôt considérer les distances minimum entre le peuplement pour parler plutôt de proximité.

Aussi, les points sur la carte pourraient correspondre au centroide des polygones, et la valeur de chaque point pourrait être pondérée par la superficie et le volume correspondant au polygone.

Les superficies des massifs doivent tenir compte de la possibilité forestière annuelle. Il faudrait faire des recherches dans ce sens pour rendre cette recherche spatiale opérationnelle et l'intégrer dans le processus de planification.

6. Évaluation opérationnelle

Lors de cette étape, nous prenons les résultats provenant des massifs forestiers et nous commençons le processus de considération biologique et légal. Pour ce faire, nous devons planifier les travaux dans le temps et l'espace.

Pour ce qui est de contrainte d'ordre spatial, nous devons nous soumettre aux normes d'interventions en milieu forestier, soit:

- la contrainte d'exploitabilité (fragilité des sites, bandes riveraines);
- la contrainte de faune (aire d'abri, pour orignal, les ravages de cerfs)
- les contraintes de paysage (1,5 km de zone de villégiature)
- les contraintes de secteur pour des fins de prévention.

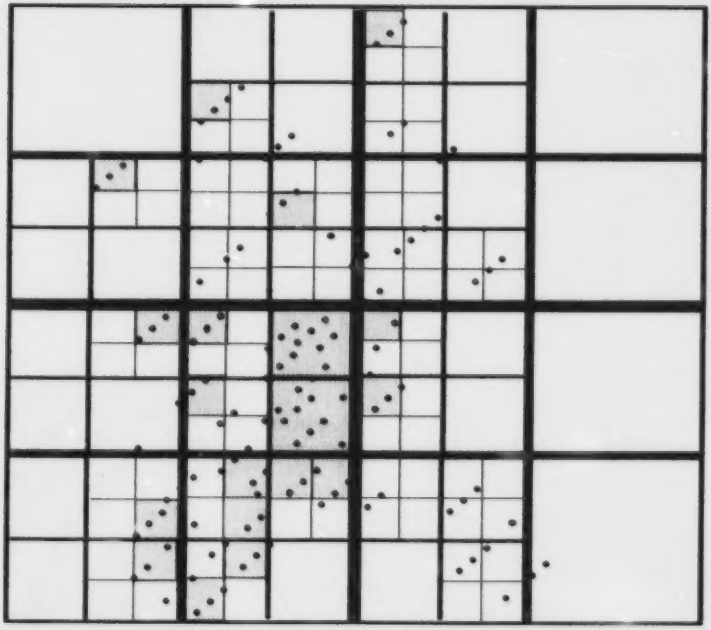

figure 3

schéma représentant une recherche spatiale selon la méthode du du quad-tree pour localiser la recherche de massif forestier le coefficient de corrélation et d'autocorrélation spatiale nous indique les secteurs correspondant à un regroupement d'un phénomène

Nous devons mettre en place des mécanismes d'analyse des relations de causes à effet qui minimiseront les risques d'erreur dans le choix des alternatives.

Par l'entremise d'un suivi spatio-temporel des travaux effectué par le gestionnaire, il peut prendre des décisions en tenant compte des résultats obtenus dans des conditions les plus similaires possibles. Mais pour ce faire, il faut connaître toutes les conditions qui prévalaient sur le terrain avant que la décision ne soit prise. En systématisant le suivi spatio-temporel et les historiques, nous pourrons diminuer les incertitudes de nos décisions. Nous agissons à l'intérieure d'écosystèmes qui réagissent spécifiquement à ces actions posées dans certaines conditions C'est à nous de s'organiser pour comprendre le plus possible les relations de causes à effet.

Le suivi spatio-temporel a des répercussions directes sur l'évaluation opérationnelle, puisque cette étape constitue en fait le coeur du processus décisionnel du gestionnaire. C'est ce suivi qui aiderait à identifier les méthodes disparates mal définies et floues qui sont les heuristiques du gestionnaire. Car dans le contexte d'aménagement de forêt complexe, le gestionnaire doit donner la vocation du secteur. Au Québec, nous sommes à l'élaboration de cartes éco-forestières qui déterminent le type de série physiographique qui prévaut dans un secteur en fonction du peuplement et du dépôt-drainage-pente. Nous voulons introduire la notion de station forestière. Cette optique fait appel à l'intégration territoriale de strates cartographiques pour pouvoir gérer la forêt par les vocations.

Malgré la technologie qui nous entoure, il faut garder en vue que c'est le gestionnaire qui prend les décisions. Il devra se bâtir une grille de priorité de situation pour qu'il puisse garder le dernier mot. La souplesse est essentielle à cette étape puisqu'une infinité de possibilité obligera la prise de décisions sur la base de jugement et de l'expérience.

7. L'évaluation de la rentabilité économique

Les logiciels de simulation économique sur le marché sont conçus pour répondre aux besoins d'ordre stratégique et tactique (plan 25 ans et 5 ans). Mais, en intégrant ce type de logiciel en dernière étape de notre processus décisionnel, nous pouvons y introduire des données plus fiables pour le niveau opérationnel. Bien qu'il n'est pas été conçu dans ce but, il peut être modifié à ces fins. Au Québec, nous avons le logiciel de système d'aménagement forestier Eco-4 qui peut étudier les différents choix de scénarios établis. On tient compte autant de la possibilité forestière que de la possibilité économique qu'on lui assigne.

Ce logiciel étudie les scénarios par strates et calcule les années optimales de récolte de ces strates. Il calculera la possibilité des produits désirés selon des critères de priorité en vue de minimiser les pertes au niveau croissance et volume.

De plus, il est conçu pour donner un feedback du choix des scénarios sur la possibilité forestière. Nous pouvons alors optimiser nos scénarios pour satisfaire le

niveau possibilité biophysique et économique forestière. Finalement, c'est un outil qui retient les quatre dimensions de l'aménagement forestier soit:

- la foresterie
- l'économie
- l'espace
- le temps.

Finalement, suite à cette dernière étape, nous pouvons classifier nos strates cartographiques par priorité d'intervention. Nous sommes alors en mesure d'effectuer des inventaires pour aller vérifier les conditions règnant sur le terrain avant la récolte.

8. L'intégration du suivi spatio-temporelle

Il nous faut d'abord procéder à l'inventaire et à l'analyse des informations que l'on possède déjà comme donnée dans l'organisation. Il faut aussi se questionner sur ce que l'on souhaite avoir comme informations dans notre suivi spatio-temporel des travaux d'aménagement.

D'abord, pour le paiement des subventions, le MFO nous oblige à effectuer des rapports d'intervention relativement aux superficies traitées; puis, pour le paiement des droits de coupes, les volumes récoltés par essences par produit

Une des premières choses à effectuer est la comparaison entre la planification et la réalisation des travaux. Nous devrions être en mesure de calculer d'où proviennent la différence et de remédier aux problèmes en mettant à jour nos planifications suite à l'analyse de ces résultats.

Il faudrait être capable d'organiser les opérations pour évaluer la provenance des volumes de bois sur le territoire. Ces chiffres nous permettront de remettre en question certaines estimations données par les inventaires. Nous pourrions aussi, par une description rigoureuse des conditions prévalant avant les opérations (qualité de site, dépôt-drainage, pente, coefficient de distribution), rectifier nos extrapolations et apporter des précisions dans le calcul de possibilité forestière. S'il faut prévoir de plus grandes superficies que prévu pour arriver à récolter les volumes minima requis pour approvisionner les bénéficiaires, il serait bon d'identifier les raisons de ce biais. Ce serait possible grâce à l'implantation d'une méthodologie dans la colligation des données provenant des travaux de récolte Est-c le pourcentage de carie qui a été sous-estimé, l'accessibilité, le volume ou la grosseur des tiges pour certains peuplements?

En référençant spatialement la provenance de nos volumes par le rattachement à des cellules les plus petites possibles, nous pouvons caractériser les peuplements forestiers.

De plus pour le suivi temporel des secteurs d'intervention, il nous faut retourner sur le terrain pour étudier le comportement du secteur suite à notre intervention. Il faut donc insérer dans nos suivis certains points de contrôle temporel pour valider nos prédictions. Pour ce faire, nous allons bâtir des modèles de suivi temporel pour identifier spatialement les points de contrôle à effectuer.

Conclusion

Par l'instauration d'un suivi spatio-temporel, on colligerait des informations qui augmenteront notre connaissance des réactions éventuelles de l'écosystème forestier. Pour optimiser l'utilisation de cette ressource, nous devons systématiser les procédures du suivi et rassembler les heuristiques de l'expert-gestionnaire de la forêt. Pour ce faire, nous devons penser à l'intégration et aux partages des informations pour que le travail de planification annuelle ne soit pas toujours à refaire. Déjà des compagnies forestières québécoises, équipées de GIS, ont instauré des procédures de suivi opérationnel pour la forêt résineuse. Cette forêt, gérée par des grosses compagnies, présente de moins grandes variances que la forêt mixte et feuillue. Les forêts mixtes et feuillues approvisionnent souvent des compagnies fabriquant des produits de sciage et/ou de déroulage de moins grande envergure qui hésite souvent avant d'investir dans la technologie GIS. Mais si on les convainc du bien-fondé...

L'un des préceptes de base à un système expert forestier est la fiabilité de la base de données. On acceptera de donner notre confiance à un système expert, pour certaines procédures, qu'à partir du moment où la qualité des données sera assurée.

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Localisation de l'aménagement forestier : Vérification d'une carte de rendement forestier créé avec l'aide d'un SIG.

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Les systèmes d'information géographique (SIG) sont de plus en plus utilisés en foresterie. Au Québec, l'implantation des SIG en forêt privée est très récente. Dans le but d'évaluer la possibilité forestière de la forêt privée du Québec, nous utiliserons des données forestières provenant de plusieurs intervenants de cette sphère d'activité (Ministère des forêts du Québec, groupement forestier et syndicat des producteurs de bois). Mais ces données, bien que très nombreuses, sont souvent très dispersées et aussi très hétérogènes pour un même territoire. Le présent projet consistera, dans un premier temps, à analyser ces données et de déterminer comment les adapter pour les intégrer à un SIG. Après avoir estimé la possibilité forestière avec un logiciel de simulation économique (ECO-4), nous serons en mesure, par la suite, de créer une carte de rendement de la forêt privée à partir de points distribués dans un territoire d'étude. Finalement, nous vérifierons le degré de précision de la carte ainsi créée par le SIG. Nous présenterons des résultats préléminaires de cette vérification de la carte obtenue par les logiciels Terra Soft et Erdas.

Localizing Forest Management: Verification of Forest Yield Map Created With the Aid of GIS

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Geographic information systems (GISs) are increasingly used in forestry However, the use of GISs in the private forest sector in Quebec is a relativel recent phenomenon. Towards the goal of evaluating the potential amount o wood which can be harvested from the private forest sector, many data a available from a variety of sources (Quebec Minister of Forests, Forestr Groupement (sic), and Union of Wood Producers). However, these data, thoug numerous, are extremely heterogeneous in nature. This project is the fir attempt to analyze these data to determine how they may be integrated into GIS. After analyzing the data using an economic simulation software (ECO-4), w will create a map wood yield for the private forest from the data point distributed on the study area. Afterwards, the precision of the map will b evaluated. Preliminary results will be presented concerning the validation o this map and the processes used to create it using TerraSoft and ERDAS software

S'informer ou décider? des SIRS aux SADRS.

Decisional Informations : From SIS to SDSS.

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Résumé

La rentabilité d'un SIRS dépend directement des possibilités offertes aux utilisateurs pour accéder aux données, pour les traiter selon leurs besoins et leurs méthodes propres et pour les représenter d'une manière "adéquate". Cependant, les logiciels de traitement, de même que les modes de représentation de l'information offerts sur le marché ne font dans la plupart des cas que reproduire les fonctionnalités "cartographiques" traditionnelles. Il existe un potentiel encore très peu exploité de techniques d'analyse, d'une part, et de gestion et de visualisation d'imagerie spatiale, d'autre part, développées dans des domaines autres que les SIRS. Analyses multi-objectifs et méthodes de simulation, images de synthèse, techniques vidéo, commencent à apparaître dans le domaine; mais une analyse systématique du potentiel offert par tous ces outils reste à faire.

La présente contribution propose un agenda de recherche et les projets présentement en cours au Centre de recherche en géomatique de l'Université Laval visant à augmenter le potentiel d'utilisation des données des SIRS par l'exploitation de ces nouvelles méthodes et technologies, afin d'évoluer des SIRS actuels vers de véritables *systèmes d'aide à la décision à référence spatiale*.

Summary

The success and cost-benefit ratio of a GIS is strongly influenced by the degree of flexibility that users may access and retrieve data, process them according to their specific requirements and represent them "efficiently". However, the actual processing software, as well as the data representation modalities for spatial data merely reproduce - although more quickly and efficiently- the traditional cartographic and visual analysis process. In scientific fields other than GIS,a large variety of data analysis, management and visualization techniques exists which could be adapted to spatial information: multi-objective analysis, simulation methods, synthesis imagery, "special-effects" and other video techniques are among them. Some of these techniques (especially for vizualisation purposes) are presently introduced in the field of spatial imagery, but their true integration into GIS should be systematically investigated.

This contribution proposes a research agenda, as well as the actual projects at the Laval University Geomatics Research Center, designed to increase the potential of GIS through the use of new analysis and representation methods and technologies, as a contribution to the progress from Spatial Information Systems towards *Spatial Decision Support Systems*.

1. Introduction

La littérature récente témoigne de l'émergence du concept de **système d'aide à la décision à référence spatiale** SADRS - en anglais Spatial Decision Support System SDSS), considéré comme le prochain pas dans les outils à développer pour la gestion du territoire et des ressources naturelles.

On constate également [TURK 1990] que l'abord des SADRS implique de prendre en compte des facteurs nouveaux, fortement dépendant des utilisateurs eux-mêmes et de leur manière de réfléchir et de décider. Ainsi, par rapport à une approche *orientée objet* qui est la tendance actuelle dans le domaine des SIRS proprement dit, on pourrait dire que le développement des SADRS doit être beaucoup plus *orienté sujet*, ce qui implique (i) le développement de nouvelles méthodes et techniques pour mieux assister le processus de prise de décision, et (ii) la recherche de modèles théoriques nouveaux pour comprendre et décrire le comportement des utilisateurs.

Le lecteur pourra trouver dans [RICHER, CHEVALLIER,1992] une illustration pratique de certaines des notions présentées dans le présent rapport.

2. Prise de décision vs aide à la décision

Il convient tout d'abord de distinguer deux problématiques à nos yeux bien distinctes,à savoir:

(a) la *prise de décision* par un système automatique autonome;
(b) l'*assistance apportée par un système informatique* à un décideur.

2.1. Systèmes autonomes de prise de décision

Il est certaines circonstances où on pourra souhaiter *substituer à l'humain un système automatique* pour prendre des décisions, par exemple:

- si la présence d'un opérateur ne peut pas être assurée en tout temps;
- lorsque la répétitivité des opérations rend une présence humaine continue peu attrayante;
- lorsque la décision doit conduire à une exécution immédiate (*temps réel*);
- si la complexité des analyses nécessaires et la rapidité de décision exigée sont *supérieures aux facultés de réaction* d'un individu.

Ce type de système se retrouvera donc surtout au *niveau opérationnel* d'une organisation [DAVIS, OLSON 1985];

L'automatisation de la prise de décision implique que le phénomène soit parfaitement connu et puisse être *modélisé de manière rigoureuse et complète*.

On visera dans ce cas le développement de systèmes autonomes (machines-outils, règlage automatique, etc.), qui devront être d'autant plus structurés, et leurs possibilités d'analyse d'autant plus riches que le problème est complexe et que le degré de liberté décisionnel est élevée.

2.2. Systèmes d'aide à la décision

Il existe une autre gamme d'activités, dans lesquelles on ressent le besoin d'assister par un système automatique une prise de décision, mais où le décideur conserve le rôle central et la responsabilité de la décision ultime [SIMOS 1990]. Contrairement aux systèmes autonomes décrits ci-dessus, on doit viser dans ce cas à *répartir judicieusement les tâches* entre décideur et système d'aide, en fonction des caractéristiques spécifiques de chacun d'eux. Les circonstances seront donc essentiellement les suivantes:

- il s'agit *d'assister un décideur* dans la réflexion et l'analyse;
- les décisions à prendre sont de plus grande portée, ayant des retombées à moyen ou long terme (*temps différé*); elles se situent donc aux niveaux *stratégique* (fixation des objectifs) ou *tactique* (définition des modalités de mise en oeuvre des objectifs) de l'organisation;
- le processus exige un haut niveau de compétence et d'expérience de la part du décideur;
- l'ensemble de phénomènes sur lesquels on veut agir sont d'un *haut degré de complexité*, ou fait intervenir des *modèles de grande dimension*; le décideur doit donc être assisté pour les travaux annexes qu'il ferait mal lui-même, ou dont l'exécution pourrait le distraire de son objectif principal;
- la prise de décision dépend de facteurs difficilement modélisables, affectifs, subjectifs, esthétiques, etc.

Dans ce cas, la valeur du système dépend avant tout de la richesse et de la puissance de l'interaction système - décideur.

Les propos ci-dessous s'attacheront à délimiter le domaine de recherche et les besoins pour ce deuxième type d'outils, qui devraient être spécifiquement conçus pour aider à la décision, et non pas pour prendre les décisions à la place de l'homme. Pour ce faire, nous allons esquisser une description du processus de prise de décision, identifier les modes d'interaction système - décideur, pour ensuite analyser les possibilités technologiques actuelles, et les besoins en recherche pour permettre l'exploitation optimale de ces technologies.

3. Processus de prise de décision et besoins du décideur

3.1. Décision isolée

La figure 1 décrit dans ses grandes lignes un processus de prise de décision au sens de la section 2.2. ci-dessus. Le décideur doit, successivement

- identifier l'**objectif** de la prise de décision;
- identifier les **paramètres** sur lesquels il peut agir (degrés de liberté), afin de
- définir diverses variantes;
- fixer les **critères d'évaluation** des variantes;
- effectuer les **analyses** et **simulations** nécessaires à l'évaluation;
- **évaluer** chacune des variantes;
- **comparer** les résultats, **choisir** la solution optimale;
- si besoin est, modifier l'une ou l'autre des prémisses du processus et recommencer l'étude.

La figure 1 met de plus en évidence (cases ombrées) les diverses étapes du processus où l'interaction entre le décideur et le système sera particulièrement importante pour l'efficacité de la prise de décision.

Pour servir un tel processus, il est nécessaire de disposer d'un ensemble d'informations, tout d'abord celles décrivant les phénomènes et objets liés au territoire, tels que contenues dans un SIRS, soit;

- la description des **objets sur lesquels portent la décision** (exemple: les routes qu'on envisage d'élargir);
- **objets interagissant** directement avec les précédents (exemple: les forêts dans lesquelles se trouvent ces routes, et qui devront être en partie abattues; les sites touristiques concernés);
- **données de comportement** des objets significatives pour les critères d'évaluation à prendre en compte (exemple: fonction de croissance des arbres);
- **le résultat de la simulation** de l'impact de la décision sur l'ensemble des objets concernés (exemple: nouvelle route; aspect prévisible de la forêt; paysages résultants, etc.).

3.2. Décisions en cascade

Une particularité des systèmes d'aide à la décision tels que nous les comprenons réside dans le fait que, dans certains cas, il ne s'agit pas seulement de prendre une décision isolée, mais de développer des **scénarios, composés de plusieurs étapes successives**, elles-mêmes pouvant inclure plusieurs décisions, et dont il s'agira d'identifier l'impact à court et long terme. De ce fait, le problème devient considérablement plus complexe, et les apports requis du système d'aide à la décision prendront une toute autre dimension.

Il s'agira en effet, en plus des éléments reliés à une décision et mentionnés à la section précédente, d'assister le décideur dans un processus en lui-même complexe; la figure 2 présente la structure générale de l'arbre constitué par l'ensemble des scénarios envisageables. Un exemple de ce type de processus de prise de décision complexe est présenté dans [RICHER, CHEVALLIER 1992].

Le système d'aide à la décision devra donc, en plus, assister le décideur pour la gestion de données relatives au processus de prise de décision lui-même, à savoir:

- les **actions possibles** sur les objets (exemple: coupe d'une cellule forestière);
- **l'interdépendance de certaines actions** entre elles (exemple: une cellule forestière ne peut être exploitée si la route qui la dessert n'est pas construite);
- les **scénarios**, successions d'actions ou de groupes d'action (exemple, plan multi-annuel de coupes forestières);
- les **variantes** envisagées;
- les **critères de choix**;
- les données présentant le **résultat de l'évaluation** des scénarios (court, moyen, long terme; exemple, images représentant l'impact paysager de coupes forestières);
- les **décisions prises** et leur justification (pour une éventuelle remise en cause ultérieure).

Le SADRS doit de plus offrir au décideur l'ensemble des fonctionnalités nécessaires pour

- l'évaluation globale de l'**impact d'un ensemble de décisions**;
- l'évaluation de ces impacts à **différents stades** (court, moyen, long terme);
- la **maîtrise de la complexité** pouvant résulter de l'analyse d'un nombre croissant de variantes.

3.3. Nature des informations

Sans entrer dans tous les détails, on peut souligner la diversité des besoins, et par conséquent la diversité souhaitable quant à la forme sous laquelle le SADRS répondra à ces besoins.

- diversité dans l'**origine des données**:
  - données factuelles (inventaires)
  - résultats d'analyses et de simulation

- diversité quant à la **nature des propriétés** (y compris de la référence spatiale)décrivant les phénomènes [CHEVALLIER, BÉDARD1991], qui peuvent être:
  - quantitatives
  - qualitative et subjective ("esthétique", qualité de vie)
  - qualitative, mais pouvant faire l'objet d'une certaine analyse quantitative (impact d'une coupe forestière sur un paysage)

- aide pour l'**accès aux informations**;

- aide à la **réflexion** (intuition, développement de variantes; maîtrise des différents scénarios);

- exécution de **simulations**;

- **assistance dans la décision elle-même** (méthodes de *goal programming* ou d'analyse multi-objectifs; analyse de sensibilité aux divers paramètres) [CARVER, 1991] [NIJKAMP et al. 1990]

- assistance dans la **comparaison des résultats** d'évaluation;

- prise en compte de **facteurs subjectifs**, assistance à la synthèse de composantes hétérogènes ($ et esthétique ...).

Il est évident qu'un tel objectif ne peut être satisfait par de "simples" bases de données, et qu'il faut chercher à exploiter au maximum l'ensemble des moyens technologiques disponibles ou en émergence, en fonction de leurs spécificités.

4. Outils technologiques

Cette section énumère un certain nombre de techniques envisageables, avec leur potentiel d'utilisation pour un SADRS.

I. Systèmes de gestion de données (SGBD)

Ces logiciels maintenant classiques peuvent servir à gérer les données non spatialisées.

II. Logiciels "GIS"

Ces logiciels (Arc/Info, MGE et autres), assortis de leurs fonctionnalités d'analyse et de représentation, semblent avant tout utilisables pour la représentation (en 2, éventuellement 3 dimensions) des inventaires et du résultat des actions envisagées

III. BD orientées - objets

De tels systèmes (p. exemple TIGRIS) peuvent être ou non adaptés à la référence spatiale (catégories I ou II ci-dessus)

IV. Systèmes à base de connaissance (systèmes-experts)

La technologie des systèmes-experts peut servir à gérer et accumuler l'expertise aussi bien sur le domaine d'activité que sur le processus de prise de décision lui-même.

V. Imagerie spatiale

Les systèmes de gestion d'images, en particulier sur disques optiques, permettent de stocker des grands volumes d'images numériques ou analogiques, avec une grande rapidité d'accès et un faible encombrement. La gestion d'images dynamiques (animation, films, vidéo)

VI. Réalité virtuelle

A partir de modèles numériques très complets, de tels systèmes offrent la possibilité de simuler avec plus ou moins de réalisme le déplacement de l'usager dans un monde virtuel, ainsi que le résultat de ses actions sur ce monde.

VII. Hyperdocuments

Orientés avant tout vers l'accès aux données, de tels systèmes peuvent offrir une grande *aide à la navigation* au travers de grands volumes d'informations complexes.

VIII. Algorithmes et méthodes d'analyse et de simulation

Il en existe dans chacun des multiples domaines d'application envisageables pour les SADRS. (voir aussi [NIJKAMP et al. 1990])

Certaines de ces techniques sont déjà couramment utilisées dans le domaine, d'autres le sont peu voir pas du tout. Il conviendra d'investiguer plus avant *quelles techniques* sont à même de contribuer à l'amélioration de *quel(s) aspect(s)* du processus décisionnel, et d'orienter en conséquence le développement de prototypes (cf ci-dessous, chapitre 6 sur les projets en cours et la méthodologie de recherche choisie)

5. Développements théoriques

En matière de systèmes d'aide à la décision, l'approche *orientée-sujet* préconisée ici pour la mise en oeuvre cohérente de ces technologies présuppose le développement ou l'amélioration de certains modèles théoriques, recouvrant divers aspects encore peu connus du processus de prise de décision. En particulier, soulignons deux domaines qui nous semblent particulièrement significatifs, et qui mériteront une attention particulière.

Connaissance des processus de formation des modèles cognitifs des décideurs

La formulation et l'évaluation d'une variante de solution induit dans l'esprit du décideur un processus mental, associant la perception et la prise de connaissance des informations descriptives du réel, la connaissance des objectifs, l'intuition, la compréhension des contraintes auxquelles toute variante est soumise. Pour qu'un système informatisé puisse valablement contribuer à la prise de décision, il faut connaître la manière dont le décideur fonctionne, et comment il identifie, va chercher et assimile les informations dont il a besoin.

Une meilleure perception de ces mécanismes mentaux permettront de préciser en particulier:

- sous quelle(s) forme(s) doivent être fournies quels types d'informations;
- quelles doivent être les caractéristiques d'un interface à l'usager qui stimulerait l'intuition et la maîtrise de la réflexion;
- quelles sont les fonctions qui doivent être exécutées par le décideur, et celles qui seront avantageusement automatisées.

Méthodes et formalismes pour le développement de SADRS

En ce qui concerne la conception de SADRS, les travaux actuels sur la modélisation de données et de traitement devront être étendus dans deux directions.

Tout d'abord, il faut investiguer la manière de modéliser et de représenter (formalisme) de manière intégrée les divers types d'informations (au sens très large) à gérer: données factuelles, expertise, données d'évaluation, description des résultats de planification. Des formalismes existent dans les divers domaines concernés, mais ils sont le plus souvent incompatibles entre eux. Divers travaux visent à développer des formalismes ou des outils CASE intégrant modèles conceptuels de données et de traitement mais il faut viser à étendre la possibilité de combiner la représentation de l'ensemble des formes de connaissances identifiées, par extension des formalismes actuels, ou par le développement de nouveaux. Dans cette perspective, le formalisme MODUL-R [CARON, 1991] représente une ébauche de solution prometteuse.

Deuxièmement, on a évoqué plus haut (ainsi que dans le tableau 3) les diverses *formes* (technologies) que peuvent revêtir ces divers types de connaissance. Les outils de modélisation de SADRS doivent permettre de tenir compte de ces diverses technologies, et de guider le concepteur vers une réalisation optimale.

SADRS et outils Upper-CASE

Au vu de ce qui précède, il apparaît à l'évidence que le développement de SADRS au sens où nous l'entendons implique obligatoirement l'utilisation d'outils CASE (Computer Aided Systems Engineering). La complexité et la diversité des types de connaissance et des technologies, et les choix judicieux à effectuer rendent nécessaire ces développements. Les travaux décrits dans

[BÉDARD 1989] et [PAGEAU, BÉDARD 1992] trouveront dans ce domaine une prolongation toute naturelle.

6. Projets en cours au Centre de recherche en géomatique de l'Université Laval

De nombreux projets de géomatique en cours ou en préparation contribueront directement ou indirectement au développement dans le domaine des SADRS. Parmi ceux qui sont plus spécifiquement orientés dans le sens présenté dans ce rapport, on peut citer:

- un projet de recherche conjoint avec une compagnie spécialisée dans l'imagerie vidéo, pour développer un formalisme de modélisation des hyper-cartes;
- un projet de développement d'un système combinant images vidéo et représentation tridimensionnel de projets architecturaux pour les analyses d'impact;
- le développement d'un SADRS en Tunisie, dans le cadre d'un projet financé par le CRDI et visant à exploiter conjointement les technologies de télédétection et de SIRS pour la prise de décision en génie rural (planification intégrée de travaux de protection des eaux et des sols);
- le processus de développement d'un SIRS est en lui-même un processus de nature décisionnel: choix des données, structuration, choix technologiques et organisationnels, configuration de l'interface à l'usager, règles sémiologiques, etc.); les travaux en cours au Centre [BÉDARD, 1989] visant à réaliser des "upper-CASE" pour le développement de SIRS peuvent donc eux-même apporter de très utiles informations aux mécanismes de prise de décision, les caractéristiques des interfaces à l'usager, etc, et, par là, contribuer à la recherche sur les SADRS.

Ces divers travaux, joints à d'autres de moindre importance ou encore en préparation, permettront de combiner trois aspects à nos yeux indispensables de la recherche dans ce domaine, soit

- la recherche fondamentale;
- le prototypage;
- un projet-pilote.

7. Conclusion

On constate que la réalisation de systèmes d'aide à la décision à référence spatiale (SADRS) pourra avantageusement tirer profit du regroupement judicieux de diverses technologies parmi les plus récentes. Mais l'intégration optimale de ces divers moyens d'aide au décideur devra se fonder sur une meilleure connaissance des mécanismes mentaux participant à la prise de décision, et sur des modèles théoriques décrivant ces mécanismes qui soient adaptés aux besoins du développement des systèmes informatisés correspondants. Le développement lui-même des applications implique (i) la création de formalismes de modélisation de la connaissance, (ii) le développement de systèmes informatiques (logiciels et matériels) intégrés de manière adéquate et (iii) la réalisation d'outils CASE complets, permettant de soutenir le développement de SADRS depuis l'inventaire des besoins jusqu'à l'implantation physique.

Le chemin à parcourir est long, et tirera avantageusement profit de la collaboration des divers domaines scientifiques concernés: sciences cognitives, sciences de l'administration et de la planification, sciences de la communication, informatique, géomatique, etc. Le problème est très complexe, et les sciences qui doivent contribuer à sa solution sont très diverses; de ce fait, l'utilisation intensive des techniques de prototypage, et le lancement de projets combinant recherches théoriques, développements technologiques et projets pilotes devrait faciliter la communication entre les divers partenaires, et la définition progressive d'un langage commun.

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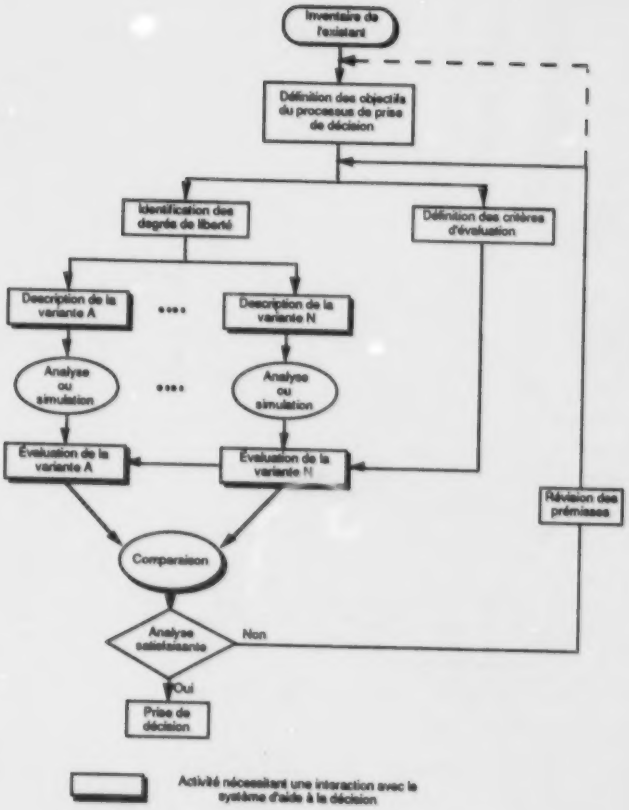

Fig. 1 - Processus de prise de décision
(décision isolée)

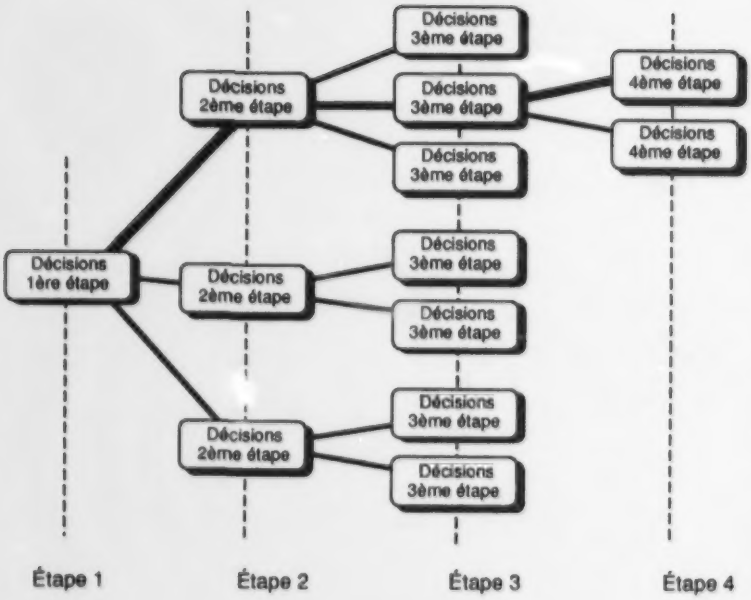

Fig. 2 - Processus de prise de décision
(décisions en cascade)

MODUL-R: UN NOUVEAU FORMALISME PERMETTANT DE MIEUX DECRIRE LE CONTENU DESIRE D'UNE BASE DE DONNEES A REFERENCE SPATIALE

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Résumé

Actuellement, les formalismes de modélisation conceptuelle ne permettent pas facilement aux utilisateurs de décrire la structure d'une base de données à référence spatiale. Ainsi, les formalismes ne permettent souvent qu'une modélisation incomplète de la référence spatiale. De plus, ils ne tiennent pas compte de la référence temporelle de façon spécifique et sont peu adaptés pour la modélisation de structures complexes. Finalement, la modélisation des données et celle des traitements pourraient être plus intégrables et la richesse d'expression des modèles pourrait vraisemblablement être améliorée. Le but de cette conférence est de présenter un nouveau formalisme de modélisation plus complet pour décrire la structure de données d'un SIG. Après avoir soulevé divers problèmes, nous décrivons de quelle façon les solutions proposées ont été intégrées pour concevoir le nouveau formalisme de modélisation «MODUL-R». Une approche intégratrice et modulaire permet de produire une modélisation plus complète et adaptable à divers contextes d'utilisation d'un SIG.

Abstract

Existing conceptual data models do not allow systems designers to efficiently describe the content of a spatial database. These models are incomplete with regard to spatial referencing, time referencing and complex schema. Data models could be easier to integrate with processes models, and their expressive power increased. The goal of this paper it to introduce a new model called MODUL-R more appropriate for GIS. We describe existing problems, the proposed solutions and thie use in MODUL-R. The result provides a more complete schema for GIS development.

1. Introduction

Dans le contexte de conception d'un système d'information à référence spatiale (SIRS), plusieurs modèles de données sont créés pour comprendre le contenu du système. Dans ce contexte, divers intervenants (concepteur, demandeur, programmeur...) communiquent leur vision de la future base de données par des modèles devant être conçus à l'aide d'un formalisme compréhensible par tous.

Possédant chacun leurs spécificités (forces et faiblesses), plusieurs formalismes graphiques actuels s'avèrent incomplets pour modéliser conceptuellement (indépendamment de la technologie [ANSI/X3/SPARC 1975]) les données à référence spatiale. Ainsi, on peut observer des lacunes concernant (1) la modélisation de la **référence spatiale**, (2) la modélisation de la **référence temporelle**, (3) le manque de simplification des modèles complexes fréquents dans les SIRS et (4) la **dichotomie données/traitements** ne favorisant pas une traduction orientée-objets de niveau logique.

Depuis déjà quelques années, la modélisation conceptuelle dans le domaine des SIRS s'est essentiellement faite en utilisant la modélisation conceptuelle traditionnelle (c'est-à-dire sans référence spatiale). Des recherches antérieures ont jusqu'à maintenant permis d'adapter entre autres le formalisme Entité-Relation au contexte particulier de modélisation en SIRS [Bédard et Paquette 1989]. Dans ce même esprit et afin d'étendre ces premiers travaux, nous proposons des solutions à certains problèmes actuels de modélisation conceptuelle dans le domaine des SIRS et les intégrons en un nouveau formalisme qui se veut plus riche et plus complet, de manière à mieux décrire le contenu désiré d'une base de données à référence spatiale.

L'approche suivie pour atteindre cet objectif a été pragmatique, itérative et demeure évolutive. Elle a été grandement influencée par l'approche *INFORMATION ENGINEERING* proposée par [Martin et McClure 1988], approche par les données favorisant l'utilisation d'outils logiciels «CASE» (Computer-Assisted System Engineering) pour faciliter le processus de conception et de gestion des modèles de données.

Dans ce qui suit, nous présentons d'abord les lacunes que nous avons observées dans les formalismes actuels. Nous présentons ensuite le formalisme MODUL-R intégrant diverses solutions aux problèmes de modélisation soulevés. Finalement, nous présentons les cinq niveaux de détail du formalisme et faisons des parallèles avec le cycle de vie d'un SIRS et la pyramide de prise de décision.

2. Certaines lacunes observées dans les formalismes actuels

Le formalisme conceptuel Entité-Relation (E/R) [Chen 1976], formalisme le plus utilisé actuellement en systèmes d'information, a fait l'objet de plusieurs adaptations et améliorations au fil des ans (dont entre autres [Spencer et al. 1990]). Pour tenir compte plus particulièrement du contexte de la référence spatiale, certaines adaptations au formalisme E/R (dialecte *Individuel* tel que décrit dans [Tabourier 1986] et [Collongues et al. 1986]) ont aussi été effectuées [Bédard et Paquette 1989].

Parmi les possibilités d'amélioration du formalisme E/R, nous en identifions quatre qui semblent particulièrement importantes:

1) Le formalisme E/R (dialecte «Individuel») a été amélioré pour tenir compte du contexte de la **référence spatiale** [Bédard et Paquette 1989], notamment par l'ajout

de pictogrammes de référence spatiale pour gérer les entités géométriques. Malgré cet important ajout, la modélisation de la référence spatiale demeurait incomplète et inconsistante à certains points de vue:

- on n'incluait pas la représentation des références spatiales alternatives dans un même modèle. Par exemple: à l'échelle 1:20 000 ou 1:50 000, un VERGER est généralement représenté par un *point*, ou par une *surface* lorsque sa dimension le justifie;
- on n'incluait pas l'agrégation spatiale pour des entités géométriques différentes. Par exemple: un RÉSEAU D'AQUEDUC peut être représenté par une agrégation de lignes (conduites) et de points (valves);
- finalement, les entités spatiales en trois dimensions n'étaient pas modélisées par ce formalisme.

2) Concernant la **référence temporelle**, celle-ci demeure difficilement représentable dans le formalisme E/R. Dans les modèles de données, le temps est souvent géré par un attribut DATE inséré dans l'entité dont on veut gérer la temporalité [Tabourier 1986]. Certains travaux, comme ceux de [Tasker 1987] et de [Langran 1989] qui proposent des sous-modèles qui peuvent être greffés aux modèles de données actuels, constituent des solutions intéressantes. Ces solutions prennent toutefois beaucoup d'espace dans les modèles conceptuels de données (MCD), ce qui augmente le volume global des modèles, diminuant d'autant la facilité de lecture et de manipulation. Finalement, les solutions actuelles ne permettent pas de références temporelles alternatives pour une même occurence de relation ou d'entité.

3) Dans le domaine des SIRS, on a souvent affaire à des **bases de données complexes** [Ossher 1987], c'est-à-dire ayant un grand nombre d'entités, de relations, d'attributs. Leur lecture, leur compréhension, leur validation et leur manipulation sont de ce fait assez ardues. Certaines solutions permettent de simplifier les modèles: technique de substitution de sous-modèle (SSM), généralisation d'entités par la création de super-entités [Bédard et Paquette 1989]. D'autres solutions permettent d'en gérer plus efficacement la complexité: regroupement thématique, utilisation de niveaux de détail au niveau conceptuel [Bédard 1990]. Les problèmes suivants demeurent toutefois:

- il n'y a aucune possibilité de regrouper ou de simplifier les relations;
- la grande quantité de détails que l'on retrouve dans le MCD rend difficile une mise en évidence de certaines composantes sémantiques du modèle (ex.: entités spatiales représentées par une surface);
- la grande taille et la complexité des modèles les rendent difficiles à dessiner, à manipuler et à valider manuellement.

4) Le formalisme E/R tel qu'utilisé actuellement en SIRS est traduisible au niveau logique en modélisation relationnelle, hiérarchique et réseau. Par contre, son manque de richesse sémantique et la **dichotomie données/traitements** généralement observée ne permettent pas de créer des modèles de données faciles à traduire vers une modélisation de niveau logique orientée-objets [Meyer 1988] [Feutchwanger 1989]. Ainsi, il serait souhaitable d'enrichir le formalisme actuel par d'autres «ajouts sémantiques»: agrégation sémantique, agrégation spatiale,

héritage plus élaboré, modélisation des activités et des traitements jointe aux données...

On remarque qu'il n'y a **aucun formalisme qui intègre à la fois ces quatre aspects** (modélisation de la référence spatiale, modélisation de la référence temporelle, modélisation complexe et modélisation données/traitements intégrée). Certains formalismes permettent toutefois de résoudre en partie certains de ces problèmes. Un formalisme intégrant ces aspects serait susceptible de procurer aux modèles une plus grande richesse sémantique; ceci serait souhaitable pour que les modèles conceptuels soient plus conformes à la réalité.

3. La structure du nouveau formalisme MODUL-R: intégration et modularité

Nous présentons ici le formalisme «MODUL-R», langage graphique qui intègre les solutions proposées aux divers problèmes soulevés. Le terme MODUL-R est d'une nature peu équivoque: «MODUL» sous-entend une **structure modulaire** de modélisation, alors que «R» signifie une **modélisation intégrée de la réalité**. Une approche **modulaire** et **intégrée** dans la création d'un formalisme, innovation importante de cette recherche, permet d'obtenir un langage **complet** mais surtout très **flexible**.

Une approche **intégrée** permet une modélisation plus **complète** et plus cohérente de la réalité. L'intégration de modèles complémentaires (ex.: modélisation conceptuelle des activités et des traitements ajoutée à une modélisation conceptuelle des données), par le biais de modules correspondants, procure une plus grande richesse sémantique des modèles, constituant alors un modèle global cohérent et «synergétique». Bien qu'il ne l'oblige pas, MODUL-R permet ainsi de modéliser globalement la réalité (selon une approche systémique) sous forme de *modèles complémentaires* les uns aux autres (modèles de données, de traitements, d'activités...) *conçus de façon intégrable*.

Une approche **modulaire** amène une grande **flexibilité** d'utilisation du formalisme. Cette flexibilité se manifeste en ce qui concerne le choix des composantes sémantiques, le choix des sections à modéliser du modèle entier ainsi qu'en ce qui a trait aux diverses possibilités de visualisation du modèle. Une grande capacité d'adaptation du formalisme à différents besoins et à divers contextes de modélisation en SIRS est ainsi possible. Selon les modules qu'il utilise, un modélisateur peut créer un modèle *intégré* très complet (ex.: modélisation des données, des traitements, des références spatiale et temporelle) ou alors un modèle conceptuel de données *traditionnel* plus simple, consistant essentiellement du formalisme E/R selon [Tabourier 1986]. L'utilisateur du formalisme doit lui-même faire, dans le choix des modules à utiliser, un compromis entre facilité de lecture et grande richesse d'expression des modèles.

Les modules du formalisme MODUL-R correspondent soit à des types de modélisation (ex.: données, traitements, activités) ou à un regroupement de certains ajouts sémantiques (ex.: références spatiale et temporelle, simplification des modèles). Ces modules se composent à leur tour de *sous-modules* regroupant certains éléments du formalisme qui constituent des «blocs» combinables par le modélisateur selon le contexte particulier de modélisation d'un SIRS. On peut dire que plus il y a de modules utilisés pour construire un modèle, plus celui-ci sera riche et plus l'utilisation d'un outil CASE (Computer-Assisted System Engineering) s'avérera indispensable.

Dans la démarche de modélisation d'un SIRS, on a jusqu'à maintenant considéré la *structure des données* comme étant la composante la plus stable dans une organisation,

principe en accord avec l'«Information Engineering». Ainsi, MODUL-R est conçu en sous-entendant une *approche par les données*. Plus particulièrement, le modélisateur utilise comme base de modélisation un *module E/R traditionnel* auquel il a la possibilité d'adjoindre selon ses besoins d'autres modules (et sous-modules) regroupant des techniques plus complètes de modélisation de la réalité. Ces techniques ajoutées dans MODUL-R proviennent du nouveau standard proposé pour l'E/R [Spencer et al. 1990], de la modélisation orientée-objets, de solutions que nous avons élaborées ou d'autres recherches.

L'analogie que nous utilisons pour représenter la structure modulaire du nouveau formalisme est celle d'une **pyramide** montrant l'agencement et la dépendance des modules les uns par rapport aux autres. Une représentation pyramidale sous-entend la nécessité d'utiliser les modules inférieurs avant les modules supérieurs.

MODUL-R se compose d'un module de base **Entité-Relation (ER)** (dialecte Individuel) permettant de modéliser les données, auquel s'ajoutent quatre autres modules complémentaires conçus à partir des problèmes déjà soulevés:

le module **Référentiel (Ré)**, le module **Action (Ac)**,
le module **Agrégation (Ag)**, le module **Simplification (Si)**.

La **figure 1** illustre la pyramide synoptique des modules de MODUL-R telle qu'elle se présente actuellement. Sauf le module **Entité-Relation (ER)**, les autres modules se composent de sous-modules. On peut aussi illustrer la structure de ces sous-modules à l'aide d'une pyramide synoptique du même type, telle que représentée à la **figure 2**.

4. Description des modules et sous-modules de MODUL-R

Nous décrivons maintenant chacun des modules de MODUL-R ainsi que les sous-modules qui les composent. Pour chaque module et sous-module, nous en expliquons d'abord l'objectif. Les composantes sémantiques et la notation utilisée sont ensuite décrites sommairement sous forme de tableau.

4.1 Le module Entité-Relation

Le module de base de MODUL-R, le module **Entité-Relation**, n'est pas décomposé en sous-modules. Il contient les composantes sémantiques de base de l'E/R (dialecte «Individuel»), soit les entités, les relations, les cardinalités et les attributs (**tableau 1a**). On retrouve aussi dans ce module les contraintes interrelationnelles (**tableau 1b**), de même que la dépendance fonctionnelle (**tableau 1c**).

Les contraintes interrelationnelles exprimant OU, ET sinon ET/OU permettent d'enrichir le modèle par l'expression de l'exclusivité ou de l'inclusivité entre plusieurs relations rattachées à une même entité. Nous proposons une notation la plus intuitive possible pour représenter ces contraintes. Dans certains cas, la notation permet à la fois d'exprimer ces contraintes et de simplifier la notation des relations.

4.2 Le module Référentiel

Le module **Référentiel (Ré)** a pour objectif de permettre de référencer les entités dans l'espace et de référencer les entités et les relations dans le temps. Il se compose de deux sous-modules: le sous-module **Référence spatiale (RéSp)** et le sous-module **Référence temporelle (RéTe)**.

Le sous-module **Référence spatiale (RéSp) (tableau 1d)** permet d'identifier les entités référencées dans l'espace à l'aide d'entités géométriques (donc cartographiables). Cette référence spatiale d'une entité est indiquée à l'aide de pictogrammes spécifiant une représentation géométrique de type POINT, LIGNE, SURFACE ou VOLUME. Ce sous-module permet aussi l'utilisation de pictogrammes de références spatiales alternatives; un tel pictogramme indique qu'à une occurence d'entité donnée peut correspondre un type d'entité géométrique ou un autre type (ex.: l'entité VILLE pouvant être représentée soit par l'entité géométrique POINT, soit par l'entité géométrique SURFACE). Lorsqu'il n'y a pas de pictogramme de référence spatiale, cela signifie que l'entité n'est pas cartographiée, donc non représentée dans le modèle cartographique.

Le sous-module **Référence temporelle (RéTe) (tableau 1e)** permet de décrire le comportement temporel des entités et des relations. Plus particulièrement, on décrit les types d'existence et d'évolution des entités et des relations. Pour ce faire, nous utilisons, selon le même principe que la référence spatiale, des pictogrammes de référence temporelle (voir Tableau 3). Dans le cas où il n'y a pas de pictogramme de référence temporelle, cela signifie qu'on ne désire pas gérer la temporalité de l'existence d'une entité ou de l'évolution selon un attribut particulier. Comme pour la référence spatiale, il est possible d'utiliser des pictogrammes de références temporelles alternatives.

4.3 Le module Agrégation

Le module **Agrégation (Ag)**, comme le module Action (décrit subséquemment), permet de rendre la modélisation conceptuelle à la fois plus riche et plus compatible avec une traduction vers la modélisation orientée-objets de niveau logique. Il permet l'agrégation sémantique d'entités et l'agrégation spatiale d'entités géométriques. Ce module se compose de deux sous-modules: le sous-module **Agrégation sémantique (AgSé)** et le sous-module **Agrégation spatiale (AgSp)**.

Le sous-module **Agrégation sémantique (AgSé) (tableau 1f)** permet la création d'entités complexes. Ces entités sont réunies implicitement par la relation «avoir» («part-of») où certaines *contraintes d'agrégation* peuvent s'appliquer. Ainsi, dans le tableau 4, une UNITÉ D'ÉVALUATION peut «avoir» aucun ou un BATIMENT. Dans ce sous-module, le critère d'agrégation utilisé pour créer des entités complexes est *sémantique* (et non spatial).

Le sous-module **Agrégation spatiale (AgSp) (tableau 1g)** a pour objectif de permettre l'agrégation entre plusieurs types d'entités géométriques. L'agrégation spatiale permet d'agréger **plusieurs types** différents d'entités géométriques (POINT, LIGNE, SURFACE et VOLUME) pour une même entité. Par exemple, un réseau d'aqueduc peut être à la fois représenté par des occurences de LIGNES symbolisant les conduites et des occurences de POINTS symbolisant les valves. Par contre, dans le MCD, on peut ne modéliser que l'entité AQUEDUC si cela correspond aux besoins de l'usager, sans pour autant créer une entité VALVE ou une entité CONDUITE; ceci illustre le fait que *l'agrégation spatiale se fait indépendamment de l'agrégation sémantique*. L'agrégation

spatiale est représentée par un *pictogramme complexe de référence spatiale* qui indique l'agrégation d'occurences de plus d'un type d'entité géométrique. Les détails concernant cette agrégation spatiale se trouvent dans le dictionnaire de données.

4.4 Le module Action

Le module **Action (Ac)** facilite la création d'un lien plus étroit entre la modélisation de données et celle des traitements. Pour ce faire, nous considérons les activités générales de l'organisation comme étant pratiquement aussi stables que la structure des données; sur cette base et du fait qu'il peut être intéressant de conserver certaines données concernant ces activités, nous créons un «pont» entre les données et les traitements par le biais d'activités dans le MCD; le MCD contient ce qui est stable dans l'organisation, soit les données et les activités générales de l'organisation, alors que ce qui est moins stable, soit les sous-activités et les traitements sous-jacents, est modélisé avec d'autres outils (ex.: diagrammes de flux de données (DFD) [Gane et Sarson 1979] [Planche 1988]). En pratique, cette intégration se manifeste par des règles qui précisent la manière dont on passe successivement de la modélisation des données à celle des activités, puis finalement à celle des traitements. Conséquemment à cette structuration, ce module se compose de deux sous-modules: le sous-module **Activités (AcAc)** et le sous-module **Traitements (AcTr)**.

Le sous-module **Activités (AcAc)** **(tableau 1h)** permet de modéliser les activités de l'organisation qui s'avèrent relativement stables et sur lesquelles on veut conserver de l'information dans le MCD (ex.: déneigement, travaux publics, entretien). Dans ce modèle, une activité est considérée comme une entité ayant les mêmes caractéristiques que les autres entités; sa notation diffère par une représentation rectangulaire aux coins arrondis. Une telle activité est décomposable en sous-activités plus détaillées; celles-ci sont modélisées avec les DFD. La stabilité doit guider le choix du niveau le plus détaillé d'activités à modéliser dans le MCD. Toute activité peut être déclenchée soit (1) par un *point précis dans le temps* (ex.: la fin d'un mois), soit (2) par un *événement* (ex.: une chute de neige). L'élément déclencheur est précisé dans le dictionnaire à l'endroit où est décrite l'activité.

Le sous-module **Traitements (AcTr)** **(tableau 1i)** permet de décrire les traitements sous-jacents aux sous-activités les plus détaillées du modèle. En effet, les sous-activités de l'organisation peuvent finalement être décomposées en traitements informatisables [Olle et al. 1988]. Pour décrire les traitements, les intrants, les extrants, les dépôts et les flux, on peut utiliser une description littérale, un organigramme ou d'autres techniques. Les liens entre les sous-activités détaillées et les traitements correspondants peuvent être exprimés dans un dictionnaire complet accompagnant la modélisation conceptuelle.

4.5 Le module Simplification

Finalement, le module **Simplification (Si)** a pour objectif de résoudre, au moyen de diverses techniques de simplification et de gestion de la complexité, le problème de modélisation complexe. Ce module se compose lui aussi de deux sous-modules: le sous-module **Abstraction (SiAb)** et le sous-module **Généralisation (SiGé)**.

Le sous-module **Abstraction (SiAb)** **(tableau 1j)** propose trois techniques: le regroupement thématique, différents niveaux de détail et diverses vues.

Le *regroupement thématique* des entités permet de créer des ensembles ayant en commun un ou plusieurs thèmes. Un thème peut être justifié par une grande interrelation d'entités entre elles, par un regroupement physique des données ou alors par l'utilisation des données par un même groupe d'utilisateurs. Par exemple: les thèmes LOISIRS, INFRASTRUCTURE et ÉVALUATION FONCIERE dans une municipalité. Une intersection entre plusieurs thèmes montre leur interrelation via une ou plusieurs entités charnières; cette interrelation peut éventuellement se traduire par un partage des données ou par une localisation commune de celles-ci. L'utilisation de *cinq niveaux de détail* (voir section 5) permet de voir un même modèle à un niveau très sommaire ou alors à un niveau très détaillé. Finalement, *différentes vues* sur le modèle sont possibles. Ces vues, possibles à différents niveaux de détail, permettent de mettre en évidence une partie du modèle (un zoom) ou de mettre en relief un ou plusieurs aspects particuliers (ex.: les activités, la référence temporelle). L'application concrète des trois techniques ci-dessus dans un seul et même modèle n'est concevable que dans un contexte d'utilisation d'outils CASE. Un tel outil supportant MODUL-R est d'ailleurs en développement [Pageau et Bédard 1992].

Le sous-module **Généralisation (SIGé) (tableau 1k)** offre pour sa part une technique de simplification des modèles: la création de super-entités et l'héritage. La super-entité est un regroupement virtuel d'entités réelles (relation implicite avec le verbe «être»). Par exemple: l'AQUEDUC «est» une INFRASTRUCTURE, l'ÉGOUT «est» une INFRASTRUCTURE. Entre une super-entité et ses sous-entités, un héritage des attributs est possible.

5. Description des niveaux de détail et exemples

Le formalisme MODUL-R, par le biais de son module Simplification, utilise **cinq niveaux de détail** permettant la modélisation de grandes applications. Ces niveaux de détail vont d'un niveau peu détaillé (niveau I) jusqu'à un niveau des plus complets (niveau V). Les composantes sémantiques de chacun de ces niveaux sont synthétisées au **tableau 2**.

Le **niveau I** (niveau sommaire) a pour objectif de donner une idée générale des thèmes qui sont modélisés. Ce niveau est surtout utilisé pour communiquer entre le modélisateur et les hauts gestionnaires du projet pour s'entendre sur le contenu global.

Le **niveau II** (niveau global) indique plus précisément les entités (incluant les entités complexes et les super-entités) qui sont incluses dans chaque thème. Il permet la communication des «grandes lignes» du projet entre le concepteur et les gestionnaires.

Le **niveau III** (niveau des thèmes) montre chaque thème séparément, en indiquant les relations concernant les entités du thème illustré. Il favorise la communication entre le concepteur et les dirigeants intermédiaires ou le personnel technique du projet. A ce niveau peuvent se déceler et se résoudre plusieurs problèmes de **responsabilité** de données.

Le **niveau IV** (niveau détaillé) favorise la communication entre le concepteur et le personnel tactique et technique du projet. Ce niveau permet d'analyser en détail toutes les relations et contraintes et de connaître le contenu sommaire de chaque entité et activité; un tel niveau de détail permet de mettre en évidence les possibilités et les limitations du modèle.

Le dernier niveau, le **niveau V** (niveau du dictionnaire intégré), contient des données et des métadonnées concernant une **intégration** des entités, des activités, des événements,

des traitements et des relations. Ce niveau s'adresse plus particulièrement au personnel tactique et technique chargé de constituer successivement les modèles logique et physique détaillés. Des recherches devraient amener le niveau V à devenir plus graphique que littéral de façon à en faciliter davantage la communication.

A partir des cinq niveaux de détail de MODUL-R, on peut entre autres faire un parallèle avec les premières étapes du cycle de vie d'un SIRS. De plus, on peut aussi faire un parallèle avec la pyramide de prise de décision dans une organisation [Le Moigne 1974]. Ces parallèles, illustrés à la **figure 3**, mettent en évidence l'utilité des niveaux de détail pour la réalisation et la communication d'un modèle dans le domaine des SIRS.

Jusqu'à maintenant, le formalisme MODUL-R a été testé dans deux contextes différents: un contexte forestier (forêt Montmorency) et un contexte urbain (secteur EPSILOG du Centre de recherche en géomatique de l'Université Laval). Dans ce deuxième cas, les thèmes suivants ont été plus particulièrement modélisés: CADASTRE, CIRCULATION, ÉVALUATION, REPERE et INFRASTRUCTURE. Nous croyons que ces deux modélisations illustrent bien la capacité d'adaptation de MODUL-R à divers besoins et à différents contextes de modélisation de données à référence spatiale.

6. Conclusion

A partir de différentes lacunes soulevées dans les formalismes actuels, nous avons élaboré certaines solutions que nous avons intégrées dans un nouveau formalisme: MODUL-R. Ce formalisme, grâce à une approche modulaire et intégrée, devrait permettre une modélisation plus complète et adaptable à différents contextes de modélisation dans les SIRS. Cette capacité d'adaptation de MODUL-R semble jusqu'à maintenant avoir été confirmée lors de son utilisation, d'abord dans un contexte municipal, puis dans un contexte forestier.

L'élaboration du formalisme MODUL-R s'inscrit dans un programme de recherche plus global du Centre de recherche en géomatique de l'Université Laval; ce programme vise à étudier les méthodes, les techniques et les outils de conception de SIRS en vue de l'élaboration d'outils «CASE» de haut niveau («upper-CASE») spécialisés.

Le formalisme MODUL-R continuera d'évoluer en fonction de recommandations venant de modélisateurs d'expérience. De plus, parmi les principaux éléments de recherche que l'élaboration de MODUL-R a mis en évidence, on peut mentionner les suivants:

- élaboration d'un langage d'interrogation du formalisme permettant de sélectionner une partie du modèle ou certains aspects («SELECT») d'un niveau de détail spécifique («FROM») en fonction de critères particuliers («WHERE»);
- étude plus poussée de la modélisation de la référence temporelle;
- étude des contraintes spatio-temporelles et de leur modélisation;
- intégration de MODUL-R dans une méthodologie de conception de SIRS.

Pour qu'il devienne un langage le plus riche possible, d'autres modules peuvent éventuellement venir compléter MODUL-R: sécurité et accès aux données, modélisation des ressources humaines, matérielles et financières, modélisation multi-médias... Il est souhaitable que MODUL-R devienne un langage riche, mais surtout qu'il demeure flexible et intuitif pour que des modèles complets et surtout facilement communicables puissent être échangés entre les différents intervenants lors de l'élaboration d'un SIRS.

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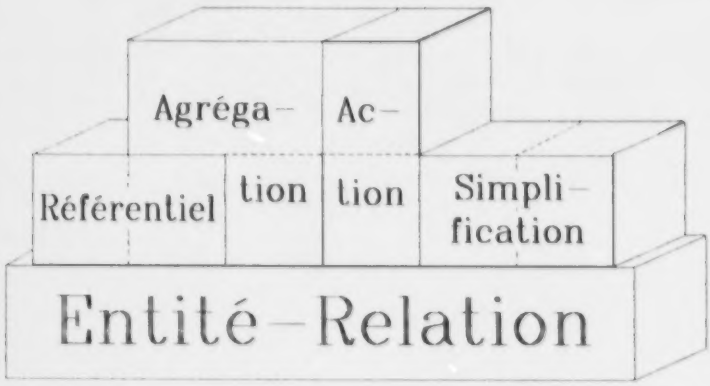

Figure 1: Pyramide synoptique des modules de MODUL-R

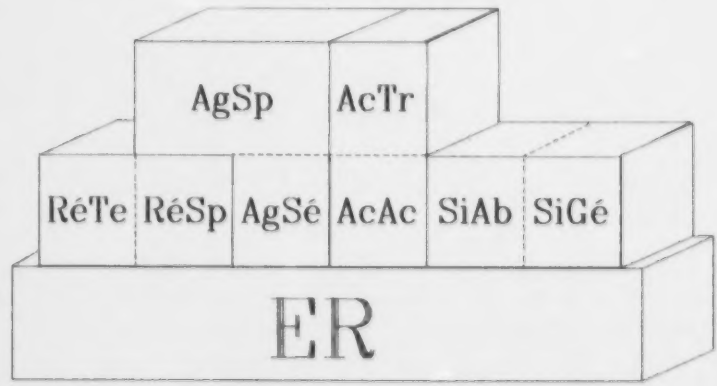

Figure 2: Pyramide synoptique des sous-modules de MODUL-R

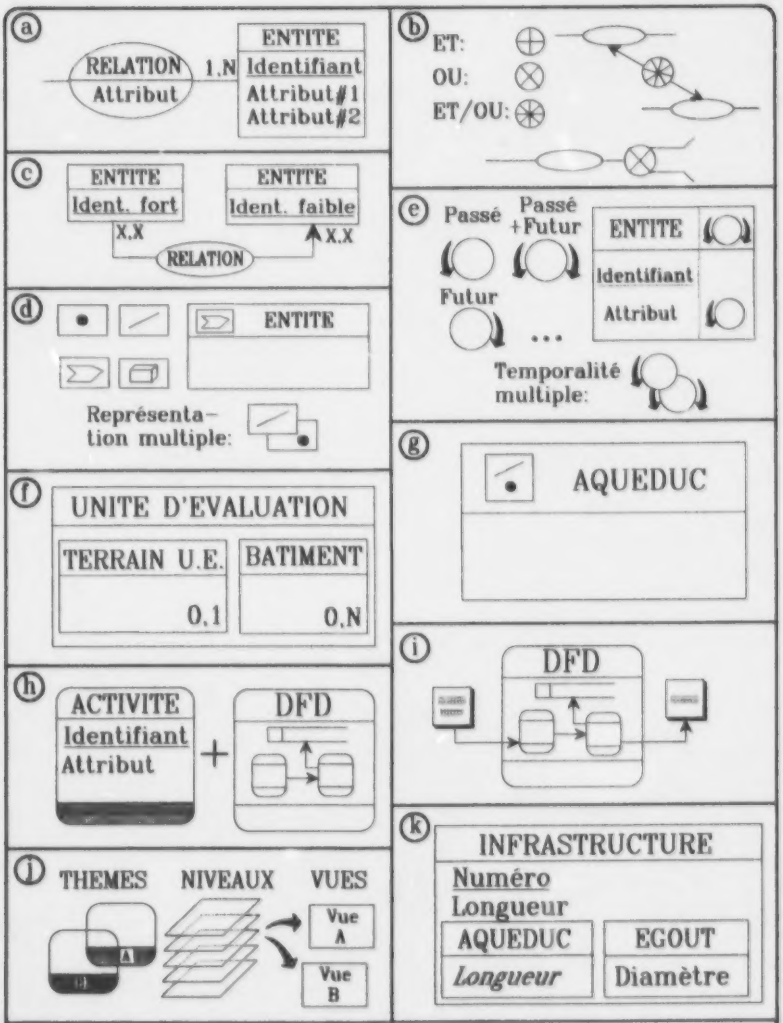

Tableau 1: Notation du formalisme MODUL-R

Niveau I	✓	✓‡															
Niveau II	✓	✓‡	✓	✓	✓	✓	✓										
Niveau III	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓‡	✓‡					
Niveau IV		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Niveau V		✓‡	✓	✓	✓	✓	✓				✓‡	✓			✓	✓	✓
Composantes Sémantiques	Thèmes	Relations	Entités	Entités complexes	Super-entités	Activités	Super-activités	Bandes de thèmes	Contraintes interrelationnelles	Référence spatiale	Référence temporelle	Héritage	Cardinalités	Dépendance fonctionnelle	Attributs	Evénements	Traitements
SOUS-MODULE:	SlAb	ER	ER	AgSé	SlGé	AcAc	SlGé	SlAb	ER	ReSp	ReTe	SlGé	ER	ER	ER	AcAc	AcTr

✱ = Représenté en partie seulement

Tableau 2: Composantes sémantiques selon les niveaux

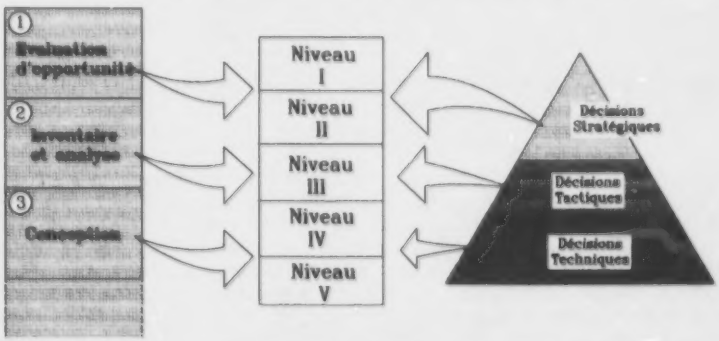

Figure 3: Parallèle avec le cycle de vie d'un SIRS et la pyramide de prise de décision organisationnelle

Implantation d'un système de gestion des ressources géomatiques d'une organisation

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Résumé

Les fonctions offertes par le méta-SIRS permettent au gestionnaire d'avoir une meilleure vue d'ensemble de l'organisation tout en ayant accès à de l'information très détaillée de cette dernière lui permettant de mieux cibler les décisions qu'il aura à prendre. Le but de cet article est de décrire la mise en place d'un tel système de gestions des ressources géomatiques d'une organisation. Nous débutons par un rappel des notions de bases et des fonctions d'un méta-SIRS. Ces notions et fonctions découlent de celles de la technologie IRDS utilisée pour le développement des grandes base de données, laquelle technologie est appliquée à la référence spatiale et intégrée physiquement ou logiquement à un atlas électronique. Puis, la discussion est portée sur la description de l'intégration du méta-SIRS dans l'organisation du point de vue fonctionnel. Ensuite, nous décrivons l'intégration physique du Méta-SIRS avec le ou les SIRS de la ou des organisation(s) impliquée(s). Un tel système devrait intéresser toute organisation désirant mieux connaître et mieux gérer l'ensemble des ressources impliquées dans la référence spatiale.

Implementation of spatial data resources management system in an organization

Abstract

Many organizations have problems managing the different aspects of data in their GIS or their Data Bases. One purpose of the 'meta-GIS' is to help the system manager having a better view on the organization and getting an access to a high level of detail informations about the resources involved in the gathering, use and dessemination of spatial data . This paper describes the development and application of the 'meta-GIS' of an organization. We firstly review the 'meta-GIS' functionalities and its fundamental concepts which originality derive from the Information Resources Dictionary System technoligy (IRDS) used for the development of data bases, and here are applied on Spatial Data. We describe the integration of the 'meta-GIS' on a design and maintenance point of view as well as the physical integration with the existing GIS(s) of a large organization. Such system should bring beneficial results to any organizations interested to a more structured approach to manage its geomatics resources.

Conception d'un système de gestion des ressources géomatiques d'une organisation

INTRODUCTION

L'organisation, à l'aide de son ou ses SIRS, gère ses données représentant le territoire (Figure 1). Par ailleurs, elle doit aussi gérer ses équipements, son personnel, ses procédures et l'information se rapportant aux données sur le territoire. Toutes ces ressources, que nous appelons "ressources géomatiques", servent à l'organisation pour acquérir, stocker, traiter et diffuser des données sur le territoire géré par l'organisation. **Ces ressources se retrouvent souvent dispersées de part et d'autre de l'organisation ce qui rend la tâche de gestion difficile voire même impossible à réaliser de façon optimale (Figure 2).**

Le manque de connaissances des données propres à l'organisation, l'importante quantité de données ainsi que leur dispersion engendre souvent de la redondance et de l'incohérence l'organisation (Larrivée et al, 1991). Mieux connaître ses ressources géomatiques permet aux gestionnaires d'avoir une vue globale de l'organisation (ex.: qui produit telles ou telles cartes? Quelle est la fréquence d'utilisation d'une donnée? Ou retrouve-t-on telles données?) et lui donner accès à de l'information très détaillée sur ses données (ex.: la fréquence de mise à jour. Les normes de captage utilisées. Les équipements qui ont servi au captage.) (Bédard et Larrivée, 1991).

À un niveau plus général on retrouve les mêmes problèmes mais cette fois entre organisations. Plusieurs organisations, souvent par un manque de connaissances de ce que les autres ont comme données, recueillent pour leur propre système d'information à référence spatiale des données qui existent déjà .

Le but de cet article est de définir les grandes lignes d'un système de gestion des ressources géomatiques (SGRG) pour ensuite décrire la mise en place d'un tel système dans une organisation. Le concept SGRG fut introduit par Bédard (1991) sous le terme "méta-SIRS", il est composé d'un IRDS (Information Resources Dictionary System) adapté, d'un atlas électronique et de fonctionnalités de gestion. Nous débutons par une discussion sur les notions de IRDS, d'atlas électronique et de fonctionnalités d'un SGRG, pour ensuite porter l'attention sur l'utilité du SGRG pour la prise de décision dans l'organisation. Enfin nous décrivons l'intégration physique du SGRG avec le ou les SIRS de la ou des organisation(s) impliquée(s).

NOTIONS ET FONCTIONNALITÉS DU SGRG (méta-SIRS)

Les problèmes soulevés plus haut existent aussi pour les systèmes d'information conventionnels. La solution adoptée pour ces derniers est la technologie IRDS (Information Resources Dictionary System, d'autres noms sont aussi utilisés: Repository, Référentiel, Inventaire,Dictionnaire, Encyclopédie) qui regroupent l'information sur les ressources propre à une organisation (Figure 3).

Les notions et les fonctions d'un IRDS ont été présentées à plusieurs endroits dans la littérature scientifique (ex.: Fife 1984, Goldfine 1985, March 1988, Moriarty 1990, Probandham et al. 1990). Deux standards internationaux ont été développés pour la définition du contenu d'un IRDS: le standard ANSI, et le standard ISO (Winsberd 1988, Altomare et al. 1988, Hazzah 1989, Winkler 1989, Selfridge 1990). Les deux groupes travaillent actuellement au dévelopement d'un standard commun (Jones 1991). La technologie IRDS a même été essayée récemment pour les SIRS dans un milieu aéroportuaire (Sani et al 1991).

La technologie IRDS favorise, entre autres, la notion du regroupement de l'information sur les données de l'organisation (Goldfine 1985). Ce regroupement est appelé "dictionnaire des ressources informationnelles" (Goldfine 1985, March et al 1988) et contient essentiellement des méta-données (i.e. des données sur les données). Cette base de données est accédée par un système de gestion (Moriarty 1990) qui permet de définir, stocker, manipuler et contrôler l'information sur les ressources organisationnelles (March et al, 1988).

Pour les systèmes d'information à référence spatiale (SIRS), on peut appliquer cette solution de façon vraiment efficace qu'après certaines adaptations et certains ajouts (Bédard 1991). Nous avons appelé le résultat obtenu de cette adaptation SGRG. Afin de répondre aux besoins propres à la gestion des ressources géomatiques, nous pouvons déjà inclure des caractéristiques qui tiennent compte de la référence spatiale. De plus, le SGRG "intègre un IRDS adapté à la référence spatiale et un atlas électronique" (Bédard 1991) (voir Figure 4). "L'atlas électronique est composé principalement des cartes index des différentes collections de cartes d'une organisation et des principaux éléments topographiques du territoire couvert." (Larrivée 1991)

Parties du SGRG:

Le système de gestion des ressources géomatiques regroupe en trois parties principales:

1) l'ensemble des données sur les ressources géomatiques,

2) un atlas électronique permettant de montrer et analyser spatialement les convertures cartographiques, les plans, les zones de relevés de qualité uniforme, etc.

3) un ensemble de fonctionnalités permettant la gestion des ressources géomatiques.

Ces trois parties fournissent la capacité de décrire minutieusement (ex.: l'information disponible, la forme qu'elle prend, comment elle est reliée à d'autre information, la qualité de cette information, l'effort d'intégration de l'information provenant de cartes ou de bases de données conventionnelles, sa localisation, sa forme géométrique, son type de représentation sur carte), de retracer, de manipuler, de stocker de façon cohérente l'information sur les ressources géomatiques d'une ou plusieurs organisations. Le SGRG contient, entre autres, les éléments suivants: collections de documents réguliers, collections de documents ad hoc, feuillets cartographiques, documents types, les classes d'objets, les attributs, les intervenants, le référentiel spatial, la description des traitements, etc. À partir des données du SGRG les utilisateurs pourront créer des rapport (producteurs des divers documents, flux d'information, etc.) et des statistiques et, avec l'aide de l'atlas électronique, des cartes thématiques.

Caractéristiques du SGRG

Il existe deux types de fonctions qui peuvent être utilisées par le SGRG. En premier lieu, on parle de **fonctions d'opération** qui permettrent des manipulations directement reliées aux données du SGRG (acquisition, édition, manipulation, interrogation, etc.), au contrôle des manipulations (qui fait quoi? Quand certains changements ont-ils été apportés? Sur quelles données? Pour quelles raisons? etc.), des fonctions qui se chargent de la mise à jour du SGRG, vérification de l'intégrité, etc.

Fonctions d'opération du SGRG:

- définir le contenu du SGRG,
- saisir et emmagasiner les données sur les ressources du SGRG,
- auto-contrôle de la méta-information du SGRG, (cette méta-information explique le SGRG lui-même, c'est-à-dire l'information sur sa propre structure, son fonctionnement, sa mise à jour, contraintes de mise à jour, etc...)
- interroger le SGRG,
- contraintes d'intégrité gérées par le SGRG:
  - au niveau de l'information du SGRG,
  - au niveau des données du SIRS.
- suivi de l'usager (qui fait quoi ?, quand ? et sur lesquelles des données ?, etc...),
- vues différentes du SIRS (selon un niveau d'abstraction désiré par l'usager ou encore pour en réduire la complexité),
- fonction d'échange et de partage des données et de l'information entre SIRS différents ou entre différents SGRG,
- module rapport, statistique et cartographie de l'atlas électronique.

En deuxième lieu, on retrouve les **fonctions de développement** des SIRS. Ces fonctions, si elles sont présentes, sont minimales (ex.: sans interface évoluée) et elles reflètent, sans en avoir toute la richesse, des fontions qui proviennent des logiciels CASE. "Les logiciels CASE sont des outils assistant le développement des systèmes d'information en permettant aux différents intervenant de mieux décrire les systèmes actuels et planifiés" (Bédard et al 1991) (ex.: outil de modélisation des données à référence spatiale, outil de symbologie, etc.). Ces fonctions ne sont pas toutes nécessaires à l'opération du SGRG, donc pourraient de ne pas faire partie de ce dernier

(Jones 1991). Cependant le mariage de ces deux types de fonctions est souhaitable, surtout que le développement du SGRG peut être fait à l'aide des fonctions de développement. La figure 5 présente les relations existantes entre les fonctions de développement (provenant d'outils CASE spécialisés) et les notions et fonctions d'opération du SGRG.

MISE EN PLACE DU SGRG POUR LA PRISE DE DÉCISION STRATÉGIQUE

Le SGRG rassemble en un tout les connaissances sur les ressources géomatiques qui généralement sont dispersées de part et d'autre d'une organisation dans une perspective bien établie de gestion de ces connaissances et de ces ressources (March et al 1989). Le SGRG fait appel à de l'information de gestion, ce système peut donc être intégré au niveau des gestionnaires là ou sont prises les décisions stratégiques et tactiques. Donc certains aspects du SGRG permettront aux gestionnaires de mieux utiliser les ressources de leur organisation. Or, d'autres aspects du SGRG vont permettre la gestion technique des données comme par exemple: la mise à jour des données, les normes d'acquisition, les instruments utilisés lors du captage, etc.

Ainsi grâce a une meilleure connaissance et un meilleur contrôle des données sur les ressources géomatiques, il est permis de croire que des économies sont rendues possibles. Économies d'autant plus importantes si le SGRG inclue, aussi, des connaissances sur les ressources de plusieurs organisations.

INTÉGRATION DU SGRG AVEC LE SIRS

On retrouve donc, dans un organisation, un ou des SIRS à l'aide duquel ou desquels elle gère ses données représentant le territoire. La mise en place d'un SRGR lui permettra de gérer de façon beaucoup plus optimale ses ressources géomatiques. Nous décrivons dans cette section les différents types d'intégrations possibles entre le(s) SIRS et le SGRG. Deux aspects principaux sont importants dans l'intégration de ces deux systèmes (voir la figure 6). D'abord, les outils nécessaires au fonctionnement du SGRG et ensuite le degré d'intégration entre le SGRG et le(s) SIRS.

Premièrement, on peut gérer les données à référence spatiale faisant partie du SIRS à partir de différents outils (logiciels et équipements): soit à l'aide d'un SGBD et de cartes papier, soit à l'aide d'un SGBD et d'un CAD ou encore soit par l'utilisation d'un GIS. Or ils est possible de faire fonctionner chacune des parties du SGRG avec les mêmes outils, c'est-à-dire: soit avec un SGBD pour l'information conventionnel et des cartes papier pour l'atlas, soit avec un SGBD pour l'information conventionnel et un CAD pour l'atlas électronique, ou soit encore avec un GIS. L'organisation n'est donc pas obligée d'acheter des nouveaux outils pour le SGRG.

Deuxièmement, des degrés différents d'intégration physique sont aussi possibles. Le(s) SIRS et le SGRG peuvent être complètement intégrés, c'est-à-dire être développés en une même application sur le ou les même(s) équipement(s) (figure 6) il est alors facile d'effectuer des analyses mettant en relation les données sur le territoire avec leurs métadonnées. Une autre solution est d'utiliser deux applications séparées (ex.: une application avec le GIS MGE pour le(s) SIRS et une autre application avec le GIS TIGRIS pour le SGRG. Ou encore une application MGE pour le(s) SIRS et une application MGE pour SGRG.). Ces applications peuvent être développées sur le ou les même(s) équipement(s) informatique(s) ou sur des équipements différents. L'utilisation d'applications différentes (et/ou d'équipements différents) fait appel à de l'importation et à de l'exportation de données pour réaliser l'intégration des deux systèmes (SIRS et SGRG). Cet import/export peut être statique ou dynamique ou encore ne pas exister entre le SIRS et le SGRG. Chaque solution présente ses avantages et ses inconvénients qu'il faut savoir utiliser selon chaque circonstance.

L'organisation peut donc décider d'utiliser les mêmes équipements et logiciels pour le SGRG qu'elle utilise pour son(ses) SIRS, ce qui aura, entre autres, pour effet de rentabiliser davantage l'équipement déjà existant du SIRS. De plus, lorsque l'organisation procède à la conception d'un SIRS avec des logiciels CASE, le chargement du SRGR est automatiquement fait (principalement lors de l'inventaire des données de l'organisation). La mise à jour se fera lors de l'opération même du SIRS et du SGRG qui sera facilitée par l'utilisation des outils CASE (Bédard et al 1991).

CONCLUSION

Les ressources géomatiques sont, plus souvent qu'autrement, dispersées de part et d'autre de l'organisation, ce qui rend difficile la connaissance et la gestion de ces ressouces d'une façon optimale. L'un des avantages de la mise en place d'un système de gestion des ressources géomatiques est de fournir une connaissance accrue de ces propres ressources (Figure 7). Connaître ses ressources géomatiques se traduit par une gestion plus efficace et contribue à réduire les problèmes de duplications et d'incohérences. Savoir que deux départements d'une même organisation sont responsables d'un même type de données et le font de façon indépendante permet de régler ce problème et de faire des économies importantes.

Le présent article résume l'état actuel de nos réflexions sur le sujet. Une liste non exhaustive des fonctionnalités d'opération du SGRG a été présentée afin de bien démontrer au lecteur l'utilité d'un tel système. Toutefois, aux fonctionnalités présentées pourraient s'ajouter certains modules qui permettraient d'étendre les capacités du SGRG. Ces modules viennent se rattacher au SGRG et seraient disponibles afin de répondre à des besoins spécifiques comme par exemple: simulateur du genre 'What If', outil de formation, module de sécurité d'accès, module de contraintes d'intégrité au niveau des outils CASE. Les recherches que nous effectuerons dans les deux prochaines années devraient permettre de finaliser cet outil.

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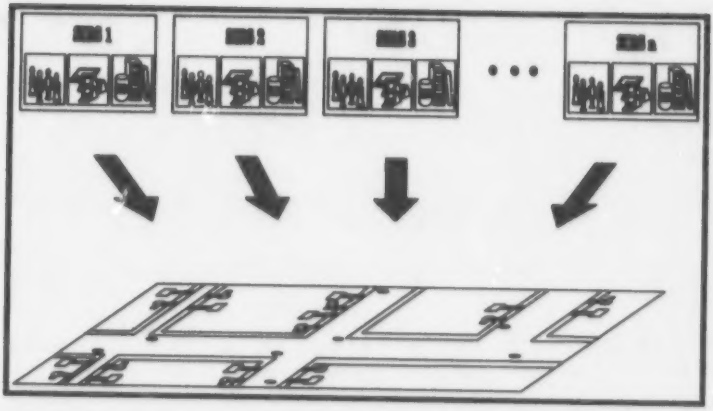

Figure 1: Un ou plusieurs SIRS sont utilisés pour gérer les données de l'organisation.

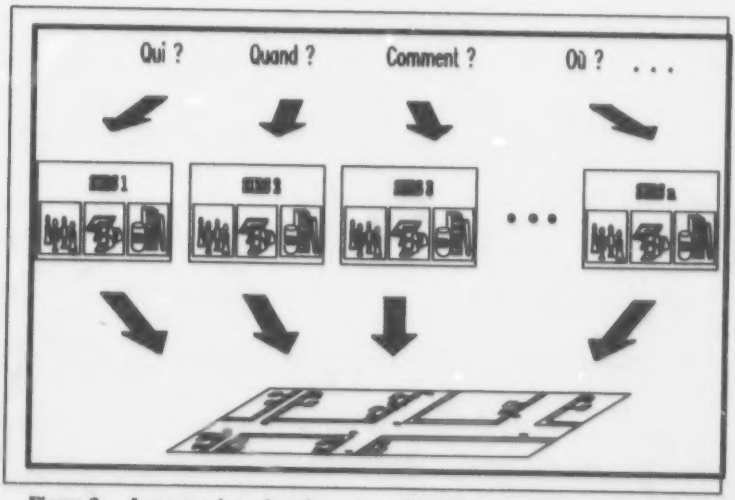

Figure 2: Lorsque les données sont dispersées de part et d'autre de l'organisation, il devient difficile de les gérer.

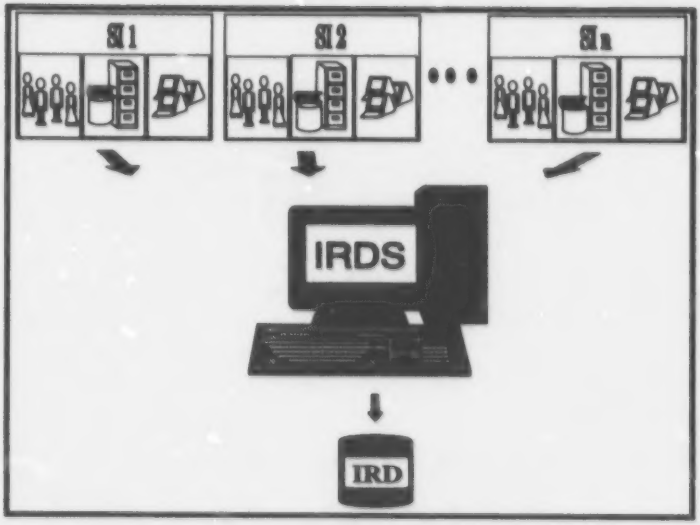

Figure 3: La solution adoptée pour les systèmes d'information traditionnel: la technologie IRDS.

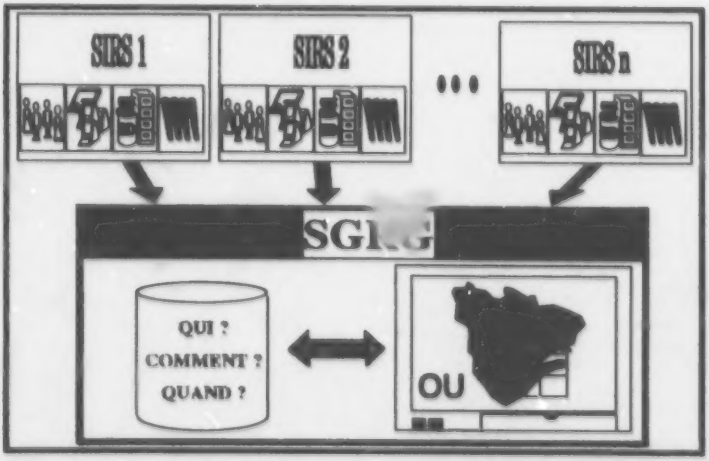

Figure 4: En plus de l'infromation traditionnelle, le SGRG doit tenir compte des données à référence spatiales.

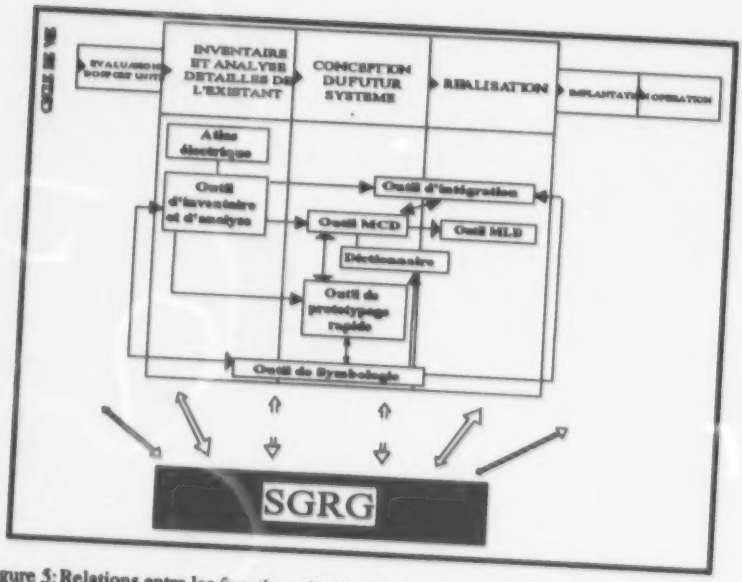

Figure 5: Relations entre les fonctions de développement et les fonctions d'opération du SGRG.

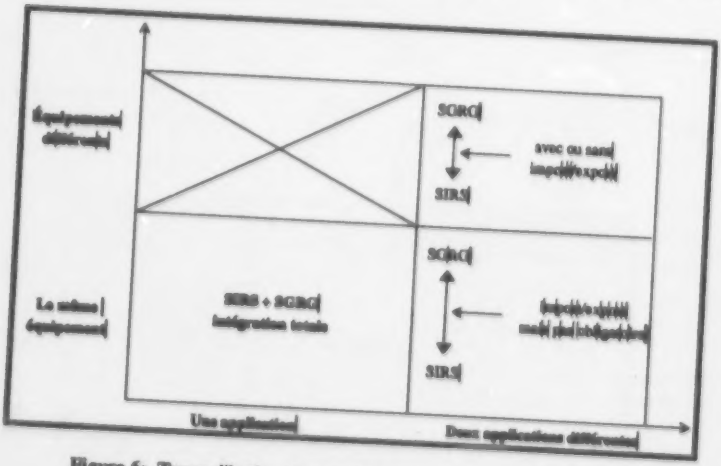

Figure 6: Types d'intégration possibles entre le SIRS et le SGRG.

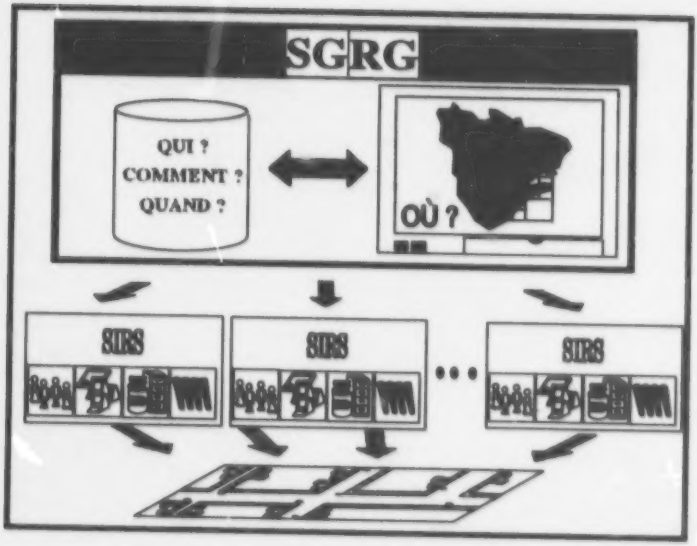

Figure 7: Une solution possible; le SGRG.

Méthode d'analyse des critères de sélection d'un outil GIS

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Résumé

Le choix d'un outil GIS est souvent, pour la municipalité qui s'y risque, une aventure hasardeuse si aucune méthode ou outil ne lui est fourni pour bien définir ses besoins en la matière.
Le but de cet article est de fournir une méthode d'analyse des principaux critères dont une municipalité doit tenir compte dans le choix d'un outil GIS.
A partir de l'existant et des besoins, d'une part, des politiques et des considérations administratives, d'autre part, les auteurs abordent la notion de ***filtre de sélection***. Ces filtres sont de deux types; les premiers regroupent les critètres de sélection objectifs (les besoins des citoyens, les éléments du SIURS existants, etc) les deuxièmes regroupent les critères de sélection subjectifs (les politiques, les considérations administratives, etc.). Ces critères reçoivent une podération et sont ensuite appliqués à une grille de comparaison de l'ensemble de l'inventaire des GIS offerts sur le marché; les auteurs font une mise en garde lors de l'utilisation de telles grilles, notamment en ce qui concerne les définitions des caractéristiques des outils GIS. La discussion finale porte sur les améliorations futures qui permettront de traduire la méthode présentée en outil informatique d'aide à la décision.
Un tel outil pourra servir d'aide à l'équipe ayant comme tâche de choisir un outil GIS, et étayer la décision de l'administrateur qui doit approuver le choix final.

The Method of Principal Criteria Analysis to Select a GIS

Abstract

Without any method to highlight the needs of a minicipality, it could be hazardous for them to select a GIS tool.
This paper proposes an analysis method which will help municipal administrations make their selection. We begin by identifying the existing resources, the needs (in term of services, technical information, etc.) the administrator though and policies; by these elements the notion of ***selection filters*** is raised. These filters are two types: the objective criteria, and the subjective criteria. All criteria receive a weighting before being applied to a inventory of the existing GISs. Some problems arise because of limitation of these system. Future needs for improving decision information systems will be discussed.
The above system will be useful to any municipalities administration who wish to integrate a GIS tool and to prop up the manager's decision who approves the final choice.

Introduction

Bien que la gestion des ressources dans une organisation s'appuie souvent sur les technologies de pointes (SGBD, logiciels de comptabilités, ...), la gestion des données sur le territoire est quant à elle encore peu informatisée. Cependant, la nécessité de gérer adéquatement le territoire amène ces organisations à s'intéresser de plus en plus au Système d'Information à Référence Spatiale (SIRS) informatisé (Smith T.R. et al., 1987, Aronoff S., 1989). Or, plus souvent qu'autrement, ces organisations investissent beaucoup d'effort dans le choix d'outils informatiques de type GIS .sans considérer leurs ressources géomatiques (l'ensemble des données sur le territoire, les ressources humaines, les équipements en place et les procédures) et leurs besoins (autant actuels que futurs) qui sont dans les deux cas parfois mal connus (Meckley B., 1987).
Le but de cet article est de fournir une méthode d'analyse des critères importants pour la sélection d'un outil GIS en milieu municipal.

I Le principe de l'outil d'aide à la sélection (Figure 4.1)

L'innovation technologique que nous connaissons depuis déjà quelques décennies (Bédard 1986, Clark et al. 1988), combinée à des besoins accrus de gestion territoriale suscitent dans les organisations municipales un intérêt marqué pour l'acquisition d'outils GIS. Toutefois, l'achat d'un tel outil s'avère une mission fastidieuse pour le néophyte en la matière. En effet, devant la panoplie des choix offerts par les différents fabricants d'outil GIS, l'organisation municipale risque de se perdre, sinon de s'éloigner de son objectif premier c'est-à-dire l'achat de l'outil GIS le plus approprié à ses besoins si ses derniers son peu ou pas connus (Oliver J.J., 1989). Toute démarche d'analyse quelle qu'elle soit, nécessite l'étude détaillée du ou des problèmes et de la conception d'une méthode de résolution (Green K.M., 1987, de Man W.H.E., 1988, Meckley B., 1987)). Or, afin de bien cerner la problématique, il s'avère primordial de bien identifier au départ les éléments qui interviendront dans l'outil l'analyse proposée (Guptill S.C., 1989). En ce qui concerne les organisations municipales, nous avons identifié quatre éléments qui influenceront le choix de l'outil GIS:

Les besoins

Les besoins se divisent en deux types c'est-à-dire: les *besoins des citoyens* (ils impliquent des besoins territoriaux comme par exemple: la planification du territoire, la fiscalité foncière, la réglementation, le transport, etc) (Tomlinson R.F., 1987) et les *besoins techniques* (reliés à la gestion administrative comme par exemple: gérer les finances municipales, gérer les immobilisations, gérer le réseau d'aqueduc, etc).

Le SIURS existant

"Le SIURS est un ensemble organisé globalement pour une municipalité, comprenant des éléments (données, équipements, procédures et ressources humaines) qui se coordonnent à partir d'une base géographique commune pour concourir à un résultat " (Bédard 1987). La décision d'informatiser un SIRS ne peut être prise sans une connaissance approfondie de la situation existante (Green 1987, Meckley 1987) d'où une connaissance approfondie de ces données, ces équipements, ces procédures et de ces ressources humaines.

Les critères techniques

Les critères techniques de sélection se définissent comme *certains facteurs techniques* ***absolument*** *souhaités par le client* comme par exemple l'environnement de travail (micro, mini, ou "main frame"), la structure des données géométriques (vectorielle topologique, ...), le système d'exploitation (DOS, UNIX, VML...), etc... Ces critères seront plus importants que certains besoins des citoyens et/ou de certains éléments du SIURS existant (Meckley 1987).

Les critères administratifs

Enfin, les critères administratifs de sélection se définissent par *certains facteurs* ***administratifs absolument*** *souhaités par le client* comme par exemple le fournisseur de l'outil GIS, son expérience, le nombre de systèmes installés, l'achat régional, etc... Ces critères seront plus importants que certains besoins des citoyens et/ou de certains éléments du SIURS existant (Meckley 1987).

II L'inventaire

L'inventaire est la composante 'intrants' du système d'aide à la sélection qui consiste à énumérer et à décrire les éléments: *besoins, SIRS existant, les critères administratifs et techniques*. "L'inventaire ne peut être faite par n'importe qui et n'importe comment. Il est important que les personnes ressources soient polyvalentes et qu'elles connaissent la majorité des éléments qui doivent faire parties de cette inventaire" (S. Larrivée et al., 1991). Nous avons regroupé en deux groupes différents les éléments de l'inventaire, c'est-à-dire: *les éléments objectifs et les éléments subjectifs*

L'inventaire des éléments objectifs

Les besoins et les éléments du SIRS existant sont regroupés comme éléments objectifs de l'inventaire

Les besoins des citoyens

Il est important de bien connaître dans une organisation municipale les besoins des citoyens mais ce qui nous intéresse notamment dans l'inventaire sont **les opérations** (*action concrète et méthodique qui vise à un résultat précis*) nécessaires pour répondre aux besoins des citoyens, **l'information** (*la connaissance des éléments qui permettent l'exécution d'une opération*) permettant d'executer les dites opérations, le ou les **mode(s) de production** de l'information (*le ou les moyen(s) qui nous permettront d'obtenir une information donnée*) utilisé(s) pour obtenir l'information et enfin une ou des **implication(s) technologique(s)** découlant de ces modes de production (*la façon dont le logiciel GIS permettra le mode de production de l'information*)(Stefanovic P. et al., 1987).

Nous proposons donc la création d'une liste où l'on pourra lire:

- les besoins des citoyens,
- les opérations municipales devant répondre à ces besoins,
- l'information permettant l'exécution de chacune des opérations,
- le(s) mode(s) de production de l'information exigé(s) pour rendre possible l'information,
- l'implication technologique correspondant à chaque mode de production de l'information.

Les éléments du SIURS existant

Choisir d'utiliser un outil GIS pour gérer un territoire municipal n'implique aucunement une remise en cause fondamentale des éléments du SIURS existant. Au contraire, décider d'informatiser en partie ou totalement un SIURS nécessite un certain respect des éléments du SIURS en place.

En effet, l'outil GIS n'étant qu'un équipement parmi tant d'autres, il devra se coordonner avec les autres équipements et les autres éléments afin d'optimiser la synergie interne du SIURS.

Evidemment, la venue de l'outil GIS impliquera un certain remaniement des données, des équipements, des ressources humaines et/ou des procédures mais sans pour autant rejeter du coup tout ce qui existait initialement. En un sens, on pourrait dire que l'implantation d'un outil GIS dans un SIURS donné devrait relever plus d'une évolution que d'une révolution.

Par conséquent, à cette étape-ci, l'inventaire des éléments du SIURS en place est très important (Green 1987) puisqu'il nous permettra de choisir l'outil GIS le plus approprié pour notre client.

Nous proposons donc de faire la liste:

- des données,
- des équipements,
- des ressources humaines,
- des procédures du SIURS existant,
- etc.

en portant une attention particulière aux éléments qui auront une influence sur le choix de l'outil GIS. Par exemple, l'inventaire de la flotte de véhicules que possède la municipalité cliente et le personnel qui les conduit ne sera d'aucune utilité lors de la recherche d'une solution en outil GIS.

Cependant l'ensemble des facteurs reliés aux ressources humaines de l'organisation sont des éléments des plus importants et qui peuvent, si l'on n'y accorde pas attention, faire échouer le projet d'informatisation du SIURS (Seldon D.D., 1987, Meckley B., 1987). Le personnel de l'organisation, au court des années, acquière des habitudes de travail dont il faut tenir compte (familier avec un type de logiciel CAD, dessiner leurs cartes manuellement, etc). De plus, ne pas tenir compte du degré de scolarité, la formation, etc., serait une erreur qui pourrait faire avorter un tel projet. Ces particularités sont très difficiles voire même impossibles à quantifier. Seul le gestionnaire à qui reviendra le choix final de l'outil pourra considérer ces éléments lors de la sélection.

L'inventaire des éléments subjectifs

On regroupe l'inventaire des critères techniques et des critères administratifs de sélection dans l'appellation éléments subjectifs.

Les critères techniques de sélection
Cette étape de l'inventaire consiste à vérifier auprès du client (l'administration municipale) s'il possède des critères techniques de sélection dont il exigera la présence dans le système d'aide afin de déterminer l'outil GIS le plus approprié.

Nous proposons de faire la liste des critères techniques du client, comme par exemple:

- un environnement de travail précis,
- le type de structure des données géométriques,
- le système d'exploitation,
- etc.

Les critères administratifs de sélection
Enfin, cette dernière étape de l'inventaire consiste à vérifier auprès du client s'il possède des critères administratifs de sélection dont il exigera la présence dans le système d'aide afin de déterminer l'outil GIS le plus approprié.

Nous proposons de faire la liste des critères administratifstion, comme par exemple:

- le fabricant de l'outil GIS,
- l'expérience du fabriquant,
- le nombre de systèmes installés,
- etc.

A la prochaine section, nous décrirons un processus permettant de résoudre le problème de sélection d'un outil GIS en utilisant les listes produite lors de cet inventaire.

3. L'ANALYSE

Après avoir inventorié les éléments objectifs et subjectifs, voyons maintenant comment utiliser les listes d'inventaire. L'analyse comprend une *pondération* des éléments inventoriés et un *processus de filtrage*.

La pondération
Nous avons déjà vu que les besoins des citoyens dans une municipalité sont satisfaits par un ensemble d'opérations. Les besoins des citoyens n'ayant généralement pas tous le même ordre de priorité (ex: s'approvisionner en eau potable vs bénificier d'aires de baignade publiques); les opérations nécessaires à la satisfaction de ces besoins auront par conséquent des niveaux d'importance variés.
Afin d'être en mesure d'identifier l'importance que revêt une opération donnée, les différents intervenants municipaux seront appelés à apposer un poids pondérateur à chacune des opérations préalablement inventoriées. La pondération proposée est de trois (3) pour les opérations jugées essentielles, deux (2) pour les opérations jugées de

moyenne importance et enfin de un (1) pour les opérations jugées souhaitables.
Pour mener à bien ces opérations, une ou plusieurs informations seront nécessaires. Comme pour les opérations, une variation de l'ordre d'importance des informations est possible. En effet, pour assurer l'exécution d'une opération donnée, la ou les informations nécessaires ne possèdent pas toutes une nécessité à caractère absolu. Le présent outil d'aide à la décision propose donc de pondérer les informations de chacune des opérations pour être en mesure de connaître leurs importances relatives. La pondération proposée (due à des facteurs de sensibilité du système de pondération) est de sept (7) pour les informations jugées très importantes, six (6) pour les informations jugées de moyenne importance et enfin de cinq (5) pour les informations simplement souhaitables.
Au début du chapitre précédent, nous avons associé à chacune des informations une ou des caractéristique(s) technologique(s) via un ou des mode(s) de production de l'information. A chacune des informations correspond donc une(des) caractéritique(s) technologique(s) que doit avoir l'outil GIS recherché. Une pondération sera encore une fois utilisée afin de mettre en valeur ces caractéristiques technologiques.
Le poids pondérateur des caractéristiques technologiques (pt) seront déterminés par la somme des résultats du produit des pondérations des opérations (po) et de chacune des informatiques (pi) auxquelles correspondent ces caractéristiques technologiques.

Ainsi: $pt = po * pi$

Mais comme il est possible qu'une caractéristique technologique soit nécessaire pour obtenir plusieurs informations différentes, on aura:

$$pt_i = \sum_{j=0}^{n} (po * pi)_j$$

où:

pt_i	correspond à la pondération totale pour une caractéristique technologique donnée;
po	correspond à la pondération d'une opération donnée;
pi	correspond à la pondération d'une information donnée;
j	correspond au nombre de fois où une pondération affecte une caractéristique technologique donnée.

Le tableau présenté à la figure 1 illustre un exemple d'opérations et d'informations pondérées ainsi que le produit de ces pondérations affecté à la caractéristique technologique correspondante.

Enfin, la somme des pondérations de chaque caractéristique technologique deviendra la pondération de l'outil GIS (P_{GIS}). C'est-à-dire:

$$P_{GIS} = \sum_{k=0}^{n} pt_k$$

où:

P_{GIS} correspond à la pondération d'un outil GIS donné;

pt_t correspond à la pondération totale pour une caractéristique technologiquee donnée;

k correspond à chacune des caractéristiques technologiques distinguant un outil GIS.

Le résultat de ce produit sera inscrit dans une grille d'outils GIS dans lequel on retrouvera les différents outils GIS disponibles sur le marché avec leurs caractéristiques technologiques respectives .

Le processus de filtration

Le résultat anticipé de l'application de filtres de sélection à une liste pondérée d'outils GIS (p. ex.: GIS World) est une sélection qui permettra de réduire la liste de départ en éliminant les outils ne répondant pas à certains critères de sélection.

Premier filtrage objectif de sélection (FOS 1): (Les besoins des citoyens)

A partir des résultats obtenus à la *figure 2* on peut appliquer un premier FILTRE OBJECTIF DE SÉLECTION c'est-à-dire éliminer tous les outils GIS dont les résultats sont inférieurs à un poids donné ou encore ne retenir qu'un certain nombre d'outils GIS et ainsi réduire la liste des outils GIS à un minimum.

Second filtrage objectif de sélection (FOS 2): (Les éléments du SIURS existant)

L'outil GIS qui sera choisi doit préférablement s'intégrer aux éléments du SIURS existant. En effet, puisque l'outil GIS est un élément parmi tant d'autres et que la coordination des éléments est très importantes dans tout système, le choix final devra tenir compte des équipements existants (ex: a-t-on un 'main frame' ou des micros, ou les deux avec l'utilisation d'un réseau?,...), des ressources humaines (ex: connaissances technique de notre personnel,...), des procédures (ex: type d'organisation municipale,..), des données (ex: structure de données présentement utilisée,...).

La première grille filtrée sera par la suite assujettie aux éléments du SIURS existant c'est-à-dire à un second FILTRE OBJECTIF DE SÉLECTION. La *figure 3* illustre un exemple de grille filtrée par les éléments objectifs de sélection (FOS 1 et FOS 2).

Premier filtrage subjectif de sélection (FSS 1): (Les critères techniques de sélection)
Le premier filtrage subjectif de sélection consiste à retirer de la grille issue des filtrages objectifs de sélection tous les outils GIS ne répondant pas aux critères techniques (subjectifs) précédemment inventoriés.

Second filtrage subjectif de sélection (FSS 2): (Les critères administratifs)
Enfin, la dernière étape de l'analyse consite à filtrer encore une fois la grille d'outils GIS affectée des trois premiers filtrages (FOS 1, FOS 2 ET FSS 1) mais cette fois en retirant les outils GIS ne répondant pas aux critères administratifs (subjectifs) de sélection.
Il est possible qu'aucun outil ne réponde aux critères utilisés en FOS 2, FSS 1 ou FSS 2. Trois alternatives sont alors suggérées: (1) réévaluer les ordres de priorité (c'est-à-dire la pondération) des opérations et des informations inventoriées, (2) filtrer avec plus de souplesse (en FOS 1) la grille de départ pondérée ou encore, comme nous le verrons plus loin, (3) reviser "à la baisse" les critères subjectifs de sélection (techniques et/ou administratifs).

A la *figure 3* nous retrouvons un exemple de grille filtrée par les éléments subjectifs de élection (FSS 1 et FSS 2).
Le filtre des éléments subjectifs ne masque pas, comme on peut le constater, les noms des outils GIS et leurs pondérations respectives (P_{GIS}).

Ceci permet de faire prendre conscience aux décideurs municipaux (clients) que leurs critères subjectifs éliminent certains outils GIS qui satisfont pourtant aux éléments objectifs. Une certaine souplesse dans leurs critères subjectifs permettrait de sélectionner des outils plus appropriés aux besoins des citoyens et aux éléments du SIURS en place.

4. SOLUTION(S)

Suite à l'inventaire et à l'analyse des éléments objectifs et subjectifs de sélection, nous obtenons quelques outils GIS.
Si le résultat de l'analyse ne nous fournit qu'un seul outil GIS, c'est qu'il est le plus approprié compte tenu des critères de sélection (objectifs et subjectifs) que nous avons inventorié au départ (ou encore l'inventaire des critères de sélections a été peut-être biaisé dès le départ). Si, par contre, l'analyse propose plus d'un outils GIS, il faudra que le client choisisse parmi ceux-ci l'outil GIS à acheter. Il est aussi tout à fait possible qu'il n'y est aucun outil GIS qui soit sélectionné, ce résultat peut vouloir dire que nous sommes trop idéaliste, trop exigeant ou encore que les besoins est été mal formulés (Dangemond J., 1987). Le choix final se fera en analysant dans le détail les solutions proposées (tests, banc d'essai,...). Ce choix devrait cependant être plus facile, parce que la réflexion se fera autour d'outils aussi appropriés les uns que les autres.
La boucle de rétroaction de l'outil de sélection permet une seconde analyse à partir des résultats obtenus d'une première analyse, après révision de l'inventaire des besoins et des critères administratifs et techniques.
Nous retouvons à la *figure 4* le modèle complet de l'outil d'aide proposé.

CONCLUSION

L'outil développé au cours de cet article procède à la sélection d'outils GIS à partir d'un inventaire pondéré propre à une organisation municipale. Le choix final d'un outil en particulier est laissé à la discrétion du gestionnaire qui est seul en mesure de se livrer à cet exercice. De plus, seul l'utilisateur peut, à partir de l'outil d'analyse proposé, interpréter (ou évaluer) les boucles de rétroaction (donc être en mesure de répondre à la question suivante: quels sont les éléments de notre inventaire qui pourront être affecté si...).

Remarques complémentaires:

- La pondération est un exercice qui exige une grande prudence. En effet, l'analyse proposée aux diverses entrevues riquera très souvent d'être confrontée à des situations où les interlocuteurs seront intransigeants quant à la nécessité des opérations auxquelles ils sont affectés: "...car nombre d'utilisateurs sont convaincus que son domaine est le plus important, donc que sa vision des choses doit primer sur les autres ..." (Chevallier, 1989). Dès lors, **l'analyse devra inciter à l'objectivité**; elle devra arbitrer ces "querelles de clocher".
- La méthode suggérée (figure 3.3) a le désavantage d'être linéaire et son utilisation peut présenter des difficultés. Sa transcription en un outil d'analyse systémique, (par exemple de type système expert) devrait permettre de mettre sur pied un outil plus efficace.

En particulier:

- Le processus de sélection présenté dans le présent travail considère que les caractéristiques techniques que l'on retrouve dans un tableau comme celui de 'GIS World' ou autres sont parfaitement comparables d'un outil à l'autre. Or, il s'avère qu'en réalité les termes utilisés pour décrire les caractéristiques techniques des outils GIS disponibles sur le marché ne sont pas toujours cohérentes (Champoux P., 1991).
  Nous suggérons donc la construction d'une base de connaissances qui permettra d'établir une classification cohérente des termes utilisés pour décrire les caractéristiques techniques des outils GIS.
  Ainsi, le système d'aide fera abstraction des termes présentement utilisés pour identifier les caractéristiques techniques, et fera ressortir de façon intelligente les outils GIS correspondants à un besoin précis.
- De plus, nous suggérons de regrouper par *thème* les caractéristiques techniques permettant de répondre à un besoin d'information précis. Ceci impliquera d'affiner la pondération discutée plus haut, par l'introduction de deux niveaux distincts, l'un pour les thèmes et l'autre pour les caractéristiques de détail.
  - L'utilisation de ces systèmes experts permettront de répondre à une question du genre: "En quoi les solutions trouvées ont-elles modifiées la formulation des besoins, de l'existant, les critères subjectifs et même la politique municipale?"

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Opérations	P_o	Informations	P_i	Caractéristiques Technologiques	$P_o \times P_i$
Gestion du réseau d'aqueduc	3	Localisation des conduites	5	Références géographiques	15
				Calcul automatique de pente	15
		Longueur des conduites	5	Mesures de distances linéaire	15
		...		...	
Gestion de la matrice graphique	2	canal de couverture	7	DOGO	14
		...		...	
Gestion du réseau de transport	3	% de pente	5	Canal automatique de pente	15
		Capacité de drainage	5	Simulation du réseau de drainage	15
				Calcul des aires de gestage	15
		...		...	
Gestion du plan d'urbanisme	3	Type de zonage	7	Superposition de polygones	21
		...		...	

Figure 1: Tableau de pondération des *opérations*, des *informations* et des *caractéristiques technologiques*.

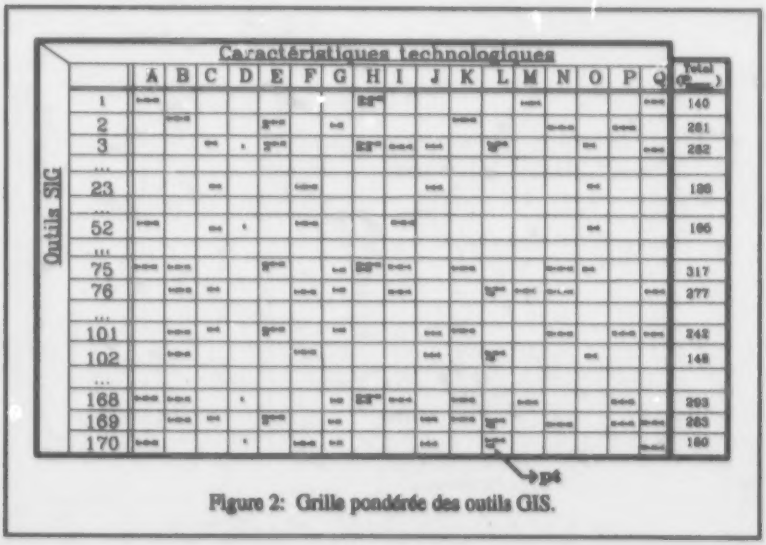

Figure 2: Grille pondérée des outils GIS.

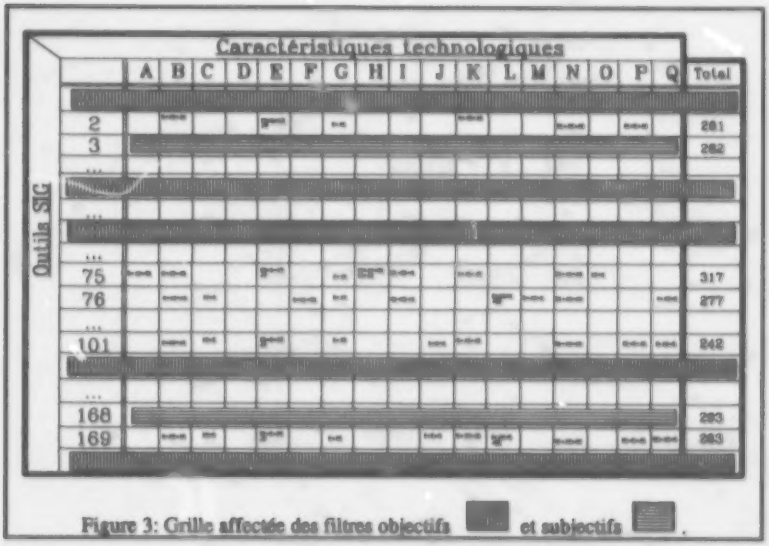

Figure 3: Grille affectée des filtres objectifs et subjectifs .

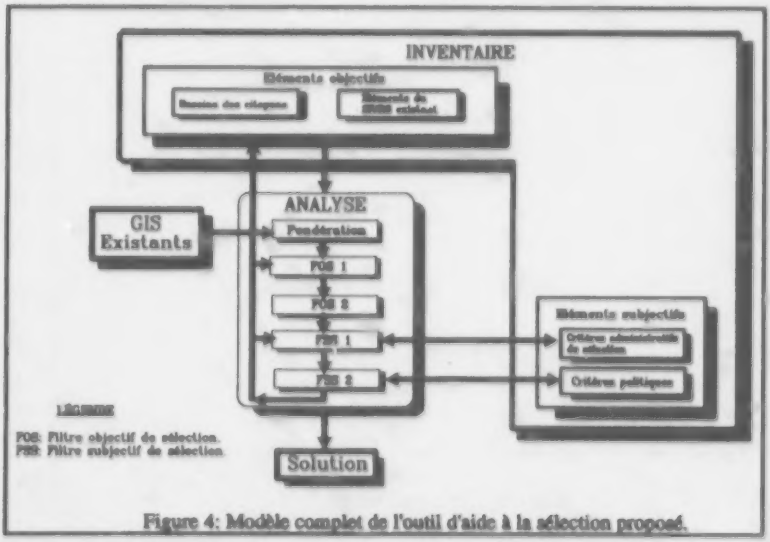

Figure 4: Modèle complet de l'outil d'aide à la sélection proposé.

OTTAWA GIS 92: Conférence proposée en séance régulière

La recherche et la formation en géomatique à l'Université Laval

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Résumé

Afin de fournir à notre société les moyens nécessaires pour gérer son territoire et ses ressources d'une façon efficace, tant du point de vue économique qu'environnemental, l'Université Laval s'est dotée de programmes de formation et d'un environnement de recherche stimulant dans le domaine de la géomatique. Ainsi, en plus d'offrir une formation scientifique et pluridisciplinaire (géodésie, cartographie, système d'information à référence spatiale, télédétection, photogrammétrie et législation foncière) au niveau du programme de 1er cycle en géomatique, le département des sciences géodésiques et de télédétection participe activement à la formation de nouveaux chercheurs. Les études gradués en géomatique permettent aux futurs chercheurs de se spécialiser dans une des disciplines de la géomatique et ceci, à l'intérieur d'un cadre de recherche unique, soit: le centre de recherche en géomatique. Doté du plus important parc technologique universitaire en géomatique au Canada et d'un budget annuel dépassant le million de dollars, le Centre de recherche en géomatique abrite des recherches sur le traitement des données acquises par des techniques spatiales et aéroportées et le développement d'outils adéquats pour l'acquisition, l'intégration, la modélisation et le traitement des données à référence spatiale. Les recherches sont principalement appliquées aux ressources naturelles, particulièrement le domaine forestier, ainsi qu'au milieu urbain. D'importants efforts sont également faits dans le but de transférer les techniques géomatiques à des domaines non-reliés au territoire (médecine, archéologie, architecture, etc.). L'équipe de recherche se compose de 12 chercheurs et 6 professionnels de recherche auxquels se joignent une vingtaine d'étudiants gradués.

Le présent article présente donc les principaux projets de recherche et de développement en cours au Centre de recherche en géomatique ainsi que la formation en géomatique offerte à l'Université Laval, particulièrement au niveau des études gradués.

The research and studies in Geomatics at Laval University

Abstract

In order to help provide our society with the required means to manage effectively its land and resources in an economical or environmental fashion, Laval University has a reliable studying program as well as an exciting research environment in the Geomatics field. Not only does the Department of Geodesy and Remote Sensing offer a scientific and multidisciplinary undergraduate curriculum (geodesy, cartography, spatial information system, remote sensing, photogrammetry and legal aspects), but it is also largely involved in the training of new scientists. The graduate studies are a useful way to specialize in one of the scientific disciplines of Geomatics and are conducted within a unique research framework: the Center for Research in Geomatics. The Center is equipped with the most important university technology park in Geomatics in Canada and has an annual budget of more than one million dollars. The actual research and development concerns the analysis of data acquired by spatial or airborne technologies and the development of new tools for the acquisition, integration, modelling and manipulation of spatial data. The fields of application are primarily natural resources, especially forestry, and urban areas. Considerable efforts are also made to transfer technologies developed in Geomatics to fields unrelated to land (medecine, archeology, architecture, etc.). The research team consists of 12 researchers, 6 research assistants and nearly 20 graduate students.

This paper presents the research and development which is presently in progress in the Center for Research in Geomatics, as well as the Geomatics curriculum offered at Laval University, particularly the graduate studies.

Présentation du logiciel Phoenix et de son utilisation pour l'inventaire des données cartographiques de la ville de Sherbrooke.

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Résumé

Lorsqu'une organisation doit rationaliser ses opérations cartographiques, implanter un GIS ou simplement connaître l'information cartographique qu'elle possède, elle doit réaliser un inventaire et une analyse de l'ensemble de ses collections cartographiques avec les objets et attributs qu'on y retrouve. Une telle opération permet de mieux identifier les ressources disponibles ainsi que les problèmes à résoudre dans l'organisation.

Afin de réduire considérablement les efforts requis pour effectuer un tel inventaire, le Centre de Géomatique de l'Université Laval a développé une méthode et créé un logiciel spécialisé pour l'inventaire et l'analyse de ces données cartographiques. Un premier prototype de cet outil fut testé dans un environnement concret, soit l'inventaire et l'analyse des données cartographiques de la ville de Sherbrooke. Le but de cet article est de présenter l'outil logiciel développé ainsi que la méthode utilisée à la ville de Sherbrooke et les résultats obtenus. Nous traiterons également de la problématique liée à la réalisation d'un tel l'inventaire, puis de son contenu. Nous terminerons par l'utilité de conserver et mettre à jour ces résultats pour l'ensemble de l'organisation. Cette présentation devrait donc profiter à tout gestionnaire et tout utilisateur de données cartographiques qui désire connaître l'ensemble des données qu'il possède ainsi que leurs caractéristiques.

Presentation of Phoenix software and its use for the inventory of cartographic data for the City of Sherbrooke

Abstract

When an organization decides to rationalize its mapping operations, to implement a GIS or simply to better know the cartographic information it possesses, it must do an inventory and an analysis of every map collection including the objects and attributes found on the map. Doing so facilitates the identification of available resources as well as problems to solve within an organization.

To significantly reduce the efforts required to do such an inventory, Laval University's Centre de Géomatique has developed specific methodology and software. A first prototype was tested in a real world situation, that is the inventory and analysis of Sherbrooke City cartographic data. The goal of this paper is to present the software tool developed specifically for this type of work as well as the methodology used in Sherbrooke City and the obtained results. We also present the problems related to such an inventory and its content. We conclude on the usefulness to keep and update this content for the overall organization. This presentation should benefit to every manager and every user of cartographic data who needs to know which data he has access to as well as their characteristics.

INTRODUCTION

oppent selon un cycle de vie composé de plusieurs étapes dont l'une
nalyse de l'existant. Cette étape est importante car elle permet de bien
tements et composantes de l'organisation actuelle. Ceci permet de
mes à résoudre, les ressources disponibles et les activités à effectuer.
rche en géomatique de l'Université Laval a développé une méthode et
de faire l'inventaire des données, traitements et composantes
tion des besoins spécifiques des SIRS. Les résultats couvrant la partie
rtographiques ont été testés à différents endroits dont la ville de
rticle débute par une description de la problématique pour ensuite se
nventaire appelé Phoenix. La description de la problématique
à la Ville de Sherbrooke sera brièvement rappelée pour, ensuite,
e au niveau de la réalisation de l'inventaire, de son contenu, de la
ultats obtenus à la Ville de Sherbrooke.

Les SIRS se déve
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cartographique rencontr
traiter de la problématic
méthode utilisée et des r

PROBLÉMATIQUE

organisations, énormément de données sont collectées, manipulées,
tc. Ceci engendre souvent de la redondance et de l'incohérence entre

Dans les grande
mises à jour, archivées,
les données. De plus,
occasionnellement ou en
ils se posent souvent de
exemple: 1) sur quels
consulté est-il à jour; 3)
officielles; 4) Est-ce que
Les décideurs re
données, problèmes d
développement de la car
sur les points suivants:
l'organisation?, a quelle
seraient les impacts du
qui pourrait être affecté
Lorsqu'une orga
conclure qu'elle a beso
connaissance incomple
redondants et très hétér
création de cartes sim
coordonnées, sans échel
contenu mais d'échelles
à l'autre; carte créée à p
De tels problèm
sommes importantes d'a
cartographiques en plus

usieurs utilisateurs connaissent mal les documents qu'ils manipulent
ore ce qui existe comme document au sein de leur organisation. Donc
questions, auxquelles ils ne trouvent pas toujours une réponse, par
cuments puis-je obtenir de l'information relative à ...; 2) le document
Quelle est la précision du document utilisé; Respecte-t-il les normes
des deux documents utilisent le même système de coordonnées; etc.
ontrent aussi des situations semblables (connaissance incomplete des
iciles à identifier) lorsqu'ils ont à prendre des décisions sur le
graphie dans leur organisation. Ils peuvent, par exemple, s'interroger
quelles cartes devons-nous numériser pour augmenter l'efficacité de
équence devons-nous faire la mise à jour de telle ou telle carte?, Quels
rait ou de la non tenue à jour d'un objet sur une collection de carte ?,
r une modification majeure apportée à une carte ?, etc.
sation éprouve de la difficulté à répondre à de telles questions, on peut
d'améliorer sa connaissance sur ses données cartographiques. Cette
est souvent liée à la production de documents cartographiques
gènes. Par exemple: mêmes objets dessinés sur plusieurs documents;
laires dans deux départements différents; cartes sans système de
sans légende; même mise à jour faite sur des documents identiques en
ifférentes; représentation non homogène des mêmes objets d'une carte
ir d'un fond de carte non à jour; etc.
existent dans toutes les organisations, à divers degrés. Il en résulte des
ent investies inutilement dans la production et le maintien des données
une utilisation moins efficace des données.

PHOENIX: L'OUTIL LOGICIEL

Un bon moyen pour une organisation de bien connaître ses données cartographiques est de faire un inventaire de celles-ci. Par la suite, l'analyse de cet inventaire permet de bien savoir "qui fait quoi", d'identifier les problèmes, de résoudre ces problèmes et de mieux orienter la production cartographique. De façon plus concrète, un inventaire des données permet de connaître ce que l'organisation possède; les principaux producteurs, utilisateurs et distributeurs; les collections de cartes mises à jour continuellement, mensuellement et annuellement; les collections de cartes les plus utilisées, les objets les plus utilisés; les normes utilisées pour l'acquisition des données; les échelles les plus souvent utilisées; etc.

Le Centre de recherche en géomatique de l'Université Laval a développé une méthode et un outil permettant d'accélérer l'inventaire et l'analyse des données cartographiques (Prince et Bédard, 1990). En 1990, la méthode et le contenu étaient définis et le premier prototype d'outil était complété. Il a les capacités suivantes:

- contenu adaptable selon les besoins;
- réalisation accélérée de l'inventaire;
- réduction du temps requis pour créer les rapports et les statistiques;
- validation de certaines informations saisies;
- plusieurs formulaires de saisie et de rapports statistiques déjà programmés;
- fonctionnement sur micro-ordinateur portable;
- lien possible avec un atlas électronique de manière à pouvoir visualiser le territoire couvert par chaque collection et créer des interrogations spatiales sur cette couverture en fonction de certaines caractéristiques de ces collections, documents, objets, attributs, producteurs, utilisateurs, normes, etc.;

Le contenu offert par l'outil Phoenix est étendu et couvre les sujets suivants:

Collection de documents
"Ensemble de documents de même type (par exemple, la carte du réseau d'aqueduc au 1:2000, i.e. cartes qui couvrent tout le territoire de la municipalité). On distingue deux types de collection: régulières et ad hoc.

Les *collections régulières* sont celles qui sont les plus couramment utilisées ou les plus importantes et dont le contenu présente un plus grand intérêt d'informatisation. Plusieurs de ces collections sont tenues à jour.

Les *collections ad hoc* sont celles utilisées que d'une façon disparate, généralement pour des projets ad hoc. Ces collections ad hoc ont été créées pour un projet particulier plutôt que pour des fins de gestion du territoire. Elles ne sont évidemment pas mises à jour" (Bédard et Larrivée, 1991).

Document type
"C'est une carte ou plan fictif complet et représentatif de l'ensemble des documents d'une collection. L'information qu'il contient est le résultat de l'analyse d'un ou quelques documents réels qui par leur contenu (classes d'objets et attributs) et leurs caractéristiques (légende, date, format, échelle) représentent bien l'ensemble de la collection de documents" (Bédard et Larrivée, 1991).

Feuillet cartographique
"Un feuillet cartographique est la représentation d'une partie d'un territoire sur tout support, physique ou magnétique" (Prince, 1990).

Classe d'objets
"Représente un groupe d'objets, d'événements, de personnes, ou de concepts qui possèdent les mêmes propriétés" (Prince, 1990). Par exemple, sur une carte topographique au 1:1000, on retrouve les classes d'objets "bâtiments", "rues", "trottoirs"; tandis que sur la carte du réseau d'aqueduc 1:2000, on retrouve des "réseaux d'aqueduc", "vannes", "bornes fontaines", etc.

Attribut
"Attribut ou propriété d'une classe d'objets (ex. *diamètre* d'un tuyau d'aqueduc, *numéro civique* d'un bâtiment) dont les valeurs apparaissent, textuellement ou graphiquement (i.e. par symbologie) sur une carte" (Bédard et Larrivée, 1991) .

Intervenant
Entité administrative à l'intérieur ou à l'extérieur de l'organisation. Les entités administratives pertinentes sont celles qui distribuent, utilisent, produisent, mettent à jour ou possèdent les données.

Référentiel
"Ensemble d'éléments formant un système de référence spatiale" (Prince, 1990). On y retrouve les systèmes de coordonnées, les datum, les ellipsoïdes de référence et les projections cartographiques.

Source
Opération de collecte de données. Soit par levés directs (à partir de la réalité (ex. relevé-terrain)) ou par levés indirects (ex. compilation photogrammétrique, numérisation de cartes).

Groupe d'occurrences
"Groupe d'occurrences d'une classe d'objets qui répondent à une des conditions suivantes: (1) elles proviennent d'un même relevé, ou (2) elles ont toutes fait l'objet du même type de généralisation, ou (3) elles ont la même précision mesurée (ex. les bâtiments situés sur la rue Chapleau côté ouest, les cellules forestières à l'est de la route 45, les regards sur le territoire couvert par l'organisation)" (Prince, 1990).

Équipement
Équipement servant à la collecte, la saisie et la maintenance des données. Par exemple, une station totale, un ordinateur, un numériseur, un logiciel, etc.

Personnel
Information sur les employés d'un intervenant et travaillant avec les données.

Projet
Projet d'un intervenant oeuvrant avec les données cartographiques.

Activité
Activité produisant des classes d'objets cartographiées sur un document (carte, plan). Par exemple, le déneigement, le balayage des rues, etc.

Une fonction principale de l'outil Phoenix est de guider l'usager dans la sélection du contenu de son futur inventaire, en lui suggérant quatre niveaux d'inventaire:

La perception préliminaire
C'est la perception qu'ont les différents chefs de service, division ou département sur leurs données cartographiques. Ceci ne constitue pas un inventaire réel des données mais plutôt un inventaire des opinions des dirigeants sur l'état des données cartographiques dans leur département.

L'inventaire préliminaire
On y retrouve les intervenants, les collections de documents, les documents types, les *groupes* d'objets, les référentiels, les normes et les équipements.

L'inventaire général
On y retrouve les intervenants, les collections de documents, les documents types, les classes d'objets, les attributs, les référentiels, les normes et les équipements.

L'inventaire détaillé
On y retrouve les intervenants, les collections de documents, les documents types, les feuillets cartographiques, les classes d'objets, les attributs, les référentiels, les normes, les sources, les représentations, les employés, les projets, les espaces de rangement, les groupes d'occurrences et les équipements.

L'usager a, de plus, le choix de faire un inventaire limité à: un secteur donné; aux photos-aériennes, cartes, images satellites, plans et/ou documents descriptifs; un Service ou une Division; une échelle donnée ou un intervalle donné; une ou plusieurs dates de publication; etc.

L'usager ne sera pas restreint à utiliser les formulaires d'inventaire tels qu'ils sont offerts par Phoenix. Ces formulaires définissent quatre types d'inventaire que nous avons jugés comme étant les plus fréquents. L'usager a la possibilité de modifier les formulaires existants en y ajoutant ou en y enlevant des données. Cette notion d'extensibilité est en accord avec les concepts proposé dans les IRDS (Information Resources Dictionary System, dont deux standards internationaux existent, soit le ANSI-IRDS et le ISO-IRDS) (Winsberd P. 1988, Jones M. 1991). "The extensibility facility of an IRDS enables the dictionary schema to be customized by the user installation, thus supporting the definition of enterprise-specific metadata" (March, 1988). Les deux groupes travaillent actuellement au développement d'un standard commun (Jones 1991).

Une fonction de contrôle assurera la cohérence des documents inventoriés à partir des choix établis par l'usager et lui fournira les formulaires appropriés à ces derniers. Si l'organisation désire par la suite étendre son inventaire, elle pourra le faire en récupérant l'information déjà recueillie.

Un premier prototype avait été développé pour réaliser l'inventaire des données de Sherbrooke. Nous développons présentement un nouveau prototype amélioré en fonction des résultats obtenus. Eventuellement l'inventaire se fera directement sur place avec un micro-ordinateur portatif (ex: les récents "notebooks" de format 8.5" x 11" x 2").

Afin de mieux gérer le territoire couvert par chaque carte et faire de l'analyse spatiale, on jumelle la base de données de l'inventaire à un atlas électronique. L'atlas est composé principalement des cartes index des différentes collections de cartes d'une organisation et des principaux éléments topographiques du territoire couvert. Nous avons développé un tel atlas sur le logiciel MGE d'Intergraph. Nous pouvons questionner l'atlas pour connaître: les collections disponibles sur telle portion de territoire; les feuillets de la carte topographique au 1:5000 pour tel secteur; les feuillets de la carte du réseau d'aqueduc qui n'ont pas été mis à jour depuis le 1er juin dernier; les collections disponibles montrant les composantes du réseau d'aqueduc pour un secteur, dessiné à l'écran par l'usager; etc.

Les résultats de l'inventaire peuvent également être utilisés lors de l'implantation d'un SIRS. Les données résultantes peuvent être récupérées et réorganisées par l'outil de modélisation de données (recherche en cours) lors de la conception du futur système.

Ces outils Upper-CASE (Phoenix, outil de modélisation, etc.) font partie d'une famille d'outils présentement en développement au Centre de recherche en géomatique et constituant un CASE intégré (Figure 1). Ces outils ont la particularité d'être compatibles entre eux via le SGRG (Bédard 1991; Dickey, Larrivée et Bédard 1992); les données résultantes de l'un peuvent être récupérées par l'autre. Ces outils permettent d'accélérer les tâches de conception et laissent ainsi plus de temps aux concepteurs pour résoudre leurs problèmes (McClure, 1988). L'utilisation de tels outils pour assister le développement de SIRS s'intègre dans le concept "Information Engineering" utilisé pour les systèmes d'information traditionnels.

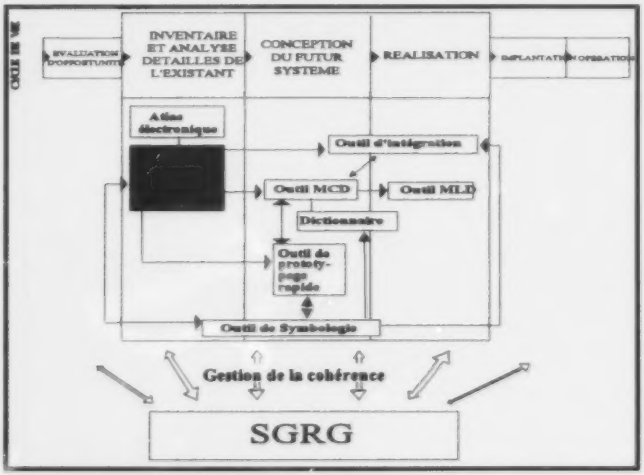

Figure 1: Les données de l'inventaire pourront être récupérées

Utilisation de Phoenix

Les premiers tests ont été effectués à Genève (Suisse), ce qui nous a permis un premier raffinage de l'outil. Un test beaucoup plus complet a été effectué à la ville de Sherbrooke (Québec), certains résultats de ces tests sont présentés à la section suivante. L'outil Phoenix a également été testé par des consultants externes (Géomatique GL) à la ville de Valleyfield (Québec).

Problématique cartographique à la Ville de Sherbrooke

La Ville de Sherbrooke, malgré le fait qu'elle possédait déjà une structure cartographique mieux organisée que la majorité des villes québécoises, demeurait consciente qu'il était possible d'améliorer davantage sa production cartographique. Les dirigeants des différents services et divisions de la Ville ont formé un comité de cartographie. Ils ont décidé de faire un inventaire pour mieux connaître leurs données cartographiques et ensuite mieux régler leurs problèmes. Cet inventaire leur permettait de mieux quantifier le tout, prioriser leurs choix, rationaliser leurs activités, etc. Ainsi, à l'automne 1990, la Ville de Sherbrooke et le Centre de recherche en géomatique ont conclu une entente pour réaliser un inventaire de données cartographiques pour l'ensemble des services de la Ville.

Problématique au niveau de la réalisation de l'inventaire

La quantité de données et la complexité de certains documents de la ville de Sherbrooke nous ont permis de bien tester notre prototype et de pouvoir l'ajuster à certaines situations que nous n'avions pas prévues. Voici quelques situations complexes rencontrées :

- plusieurs échelles pour une même collection de cartes et sur un même feuillet cartographique;
- plusieurs producteurs, responsables de la mise à jour, et distributeurs pour une même collection de documents;
- plusieurs documents cartographiques sur un même support tangible;
- une même collection de documents sur plus d'un support (film, papier, micro-film);
- document créé à partir d'un fond de carte non à jour;
- ajout d'un attribut à un objet déjà représenté sur le fond de carte d'une carte thématique;
- etc.

Malgré la richesse de la structure de données de Phoenix, tous les cas possibles ne peuvent être réglés. Afin de remédier à cette situation, nous avons structuré notre outil de manière à ce que l'usager puisse ajouter de nouvelles entités à la structure de données. Un espace "remarque" est aussi disponible pour chaque entité, pour permettre à l'usager d'inscrire de l'information ad hoc sans avoir à créer nécessairement une entité.

Inventaire réalisé à Sherbrooke

Le contenu de l'inventaire effectué à Sherbrooke a été défini par la Ville de Sherbrooke en s'inspirant du contenu offert par le Centre de recherche en géomatique. Voici les principaux domaines sélectionnés par la Ville auxquels certaines données importantes pour eux, ont été ajoutées: 1) **Collection de documents** (On distingue deux types de collection: régulières et ad hoc); 2) **Document type**; 3) **Classe d'objets**; 4) **Attribut**; 5) **Intervenant**; 6) **Référentiel**.

L'extrait suivant du rapport remis à la Ville de Sherbrooke (Larrivée et Bédard, 1991) décrit bien la méthode choisie: "la première étape consistait à déterminer la portée de l'inventaire en fonction du mandat. Ainsi, les choix suivants ont été faits:

1- Limiter l'inventaire des collections ad hoc à leur seul dénombrement et énumération;
2- Ne pas tenir compte des photographies aériennes ni des images satellitaires;
3- Ne pas tenir compte des cartes possédées par la Ville mais couvrant uniquement d'autres régions;
4- Ne pas tenir compte du nombre de reproductions en circulation ou entreposées.

Par la suite, le chargé de projet prenait connaissance des besoins de la Ville de Sherbrooke, il adaptait le contenu de l'inventaire et la méthode à suivre en fonction du mandat.

La nature du mandat limitait de plus l'inventaire aux seules données cartographiques (i.e. représentées graphiquement sur les cartes). Ainsi, cet inventaire ne *couvre pas les attributs descriptifs (des objets cartographiés) qui sont conservés sur des documents ou des fichiers informatiques autres que des cartes* (ex. données du rôle d'évaluation qui n'apparaissent pas sur la matrice graphique).

L'inventaire fut réalisé par une seule personne, afin d'obtenir une plus grande cohérence pour l'interprétation des collections, des objets, des attributs, etc.

Les services, divisions et organismes para-municipaux identifiés par la Ville furent tous visités par le chargé de projet et chaque collection a été analysée avec ces derniers. Lors des visites, plusieurs notes ont été prises sur place tout en enregistrant la majorité des conversations avec les représentants de la Ville de manière à pouvoir s'y référer en cas d'ambiguïté ou d'incertitude sur une information transmise.

Un extrait d'une collection (carte et légende) était fourni au chargé de projet lorsque possible et utile. Certaines notes ont même été inscrites sur ces documents directement lors des visites.

La saisie des données d'inventaire a été effectuée sur les ordinateurs de l'Université Laval avec le prototype de logiciel adapté pour ce projet. Le résultat de l'inventaire fut présenté à la Division Géomatique pour validation."

L'inventaire et l'analyse des cartes et plans de la Ville de Sherbrooke ont été réalisés par une seule personne en 10 semaines environ, soit 1/2 journée par collection. Cet inventaire de 101 collections régulières de documents, contenu dans 5 volumes de 1823 pages au total, a été remis à la Ville de Sherbrooke le 7 février 1991. Il comprend la description de chacune des collections régulières (nom, thème, système de découpage, but, nombre de documents, etc), de chacun des documents type (échelle, méthode de conception, date de publication, fréquence de mise à jour, support utilisé (tangible et/ou magnétique), etc.), des normes (captage, conception, représentation), des intervenants (producteur, propriétaire, distributeur, responsable de la mise à jour, utilisateur), de la satisfaction et des améliorations proposées par les intervenants, des référentiels utilisés (système de coordonnées, projection cartographique, datum, unité de mesure, etc.), de chacune des classes d'objets représentées sur chaque collection (nom, description

géométrique, responsable d[illegible]se à jour, utilisateurs, etc) et de chacun des attributs qui décrivent ces classes d'objets (nom, valeurs possibles, utilisateurs, etc.). On retrouve de plus, au début du premier volume de l'inventaire, la liste par intervenant des collections de documents ad hoc et une évaluation approximative du nombre de documents pour chacune d'elle. De manière à faciliter la recherche dans l'inventaire, celui-ci est classé par ordre alphabétique de collection. De plus, une table des matières et un index des classes d'objets en font partie. Afin de bien faire ressortir la situation cartographique à la Ville de cet inventaire, plusieurs listes, tableaux, catalogues et graphiques ont été créés.

Voici quelques exemples de résultats:

- Atlas urbain;
- Carte cadastrale 1 : 1000;
- Carte de compilation des relevés terrain;
- Croquis des stationnements entretenus par la Ville;
- Plan d'aménagement du centre-ville;
- etc.

Les résultats statistiques obtenus peuvent être de format tableau ou graphique:

ITEMS	NOMBRE TOTAL
Collections de documents réguliers	101
Collections de documents ad hoc	113
Collections numériques	10
Collections produites par la Ville	78
Feuillets cartographiques	7026
Classes d'objets	614
Attributs	679
Systèmes de coordonnées	5
Datum	3
Entités administratives	17
Collections sans légende	48

Tableau 1: Statistiques globales de l'inventaire de données cartographiques de la Ville de Sherbrooke.

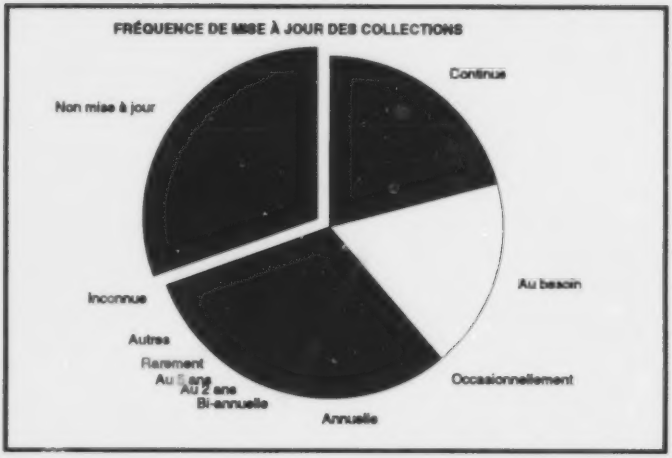

Figure 2 : Graphique illustrant les fréquences de mise à jour des collections de documents.

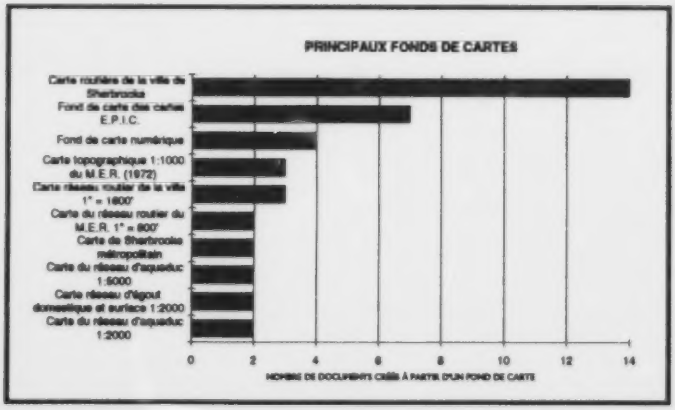

Figure 3: Graphique illustrant la fréquence d'utilisation des fonds de cartes.

CONCLUSION

Les résultats obtenus à Sherbrooke démontrent que posséder un inventaire des données cartographiques permet d'identifier plus facilement les problèmes de redondance et d'incompatibilité de données cartographiques. Il permet de mieux prioriser les actions et d'orienter le développement à court, moyen et à long terme de la cartographie d'une organisation. Il sert aussi comme dictionnaire de leurs données cartographiques, référence pour la symbologie et a terminologie, et pour faire des projets d'implantation de SIRS. Les analyses leur ont aussi permis d'identifier les principaux producteurs et utilisateurs des documents cartographiques; les flux d'information entre les producteurs et les utilisateurs ainsi que le volume de données cartographique de la Ville, autant en terme de document que de classes d'objets; les efforts de tenue à jour; etc.

L'utilisation d'un outil, tel que Phoenix, pour faire l'inventaire augmente la qualité des résultats et réduit le temps requis pour créer les rapports et les statistiques déjà programmés, il possède une série de formulaires de saisie et de rapports statistiques déjà programmés, il fonctionne sur PC portable, il peut être lié à un atlas électronique et être intégré à d'autres outils CASE. Cela en fait donc un outil intéressant autant pour connaître simplement la situation actuelle que pour développer un SIRS.

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CONCEPTION D'UN OUTIL CASE POUR LA MODÉLISATION DES DONNÉES À RÉFÉRENCE SPATIALE.

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Résumé

Lors de la conception d'un Système d'Information à Référence Spatiale (SIRS), une des étapes importantes est la modélisation conceptuelle des données. De plus en plus, la modélisation des données est faite à l'aide d'ateliers de génie logiciel (AGL, également connus sous l'acronyme anglais CASE, Computer-Assisted System Engineering). Cependant, les outils AGL actuels pour la modélisation des données pourraient être améliorés pour la modélisation des données à référence spatiale.

Cet article présente les principales considérations à tenir compte pour la conception d'un outil AGL adapté à la modélisation des données à référence spatiale. Cet outil utilise MODUL-R, un nouveau formalisme de niveau conceptuel qui adapte le formalisme entité-relation à la référence spatiale.

Nous énonçons les principales fonctions que doit contenir un bon outil AGL pour la modélisation de données. Ensuite, nous discutons des caractéristiques propres à la modélisation des données à référence spatiale ainsi que des relations entre l'outil de modélisation et d'autres outils AGL développés également au CRG. Finalement, nous présentons quelques exemple de l'interface du prototype qui est présentement en développement au CRG. Cette présentation s'adresse surtout aux modélisateurs qui s'intéressent plus particulièrement aux données à référence spatiale.

Abstract

One of the most important tasks to design an organisational Spatial Information System (SIS) is conceptual data modeling. Now, data modeling is made mostly with the help of CASE tools (Computer-Assisted System Engineering). However, present CASE tools are not specialized for spatial data modeling.

In this paper, we present the basis of a CASE tool adapted for spatial data modeling. It uses MODUL-R, a new conceptual formalism that extends the entity-relationship formalism for spatial data. First, we present the functions of a good CASE tool. Secondly, we describe the necessary functions for spatial data modeling, and links between the modeling tool and other CASE tools developped at the CRG. Finally, we present examples of our prototype user interface. This paper is intended to designers interested in spatial data modeling.

1. INTRODUCTION

De plus en plus, les outils AGL sont utilisés lors du développement de systèmes d'information traditionnels, i.e. sans référence spatiale (SI). Cependant leur utilisation lors de la conception de SIRS est moins répandue parce qu'ils sont moins connus par les spécialistes des SIRS et qu'ils ne sont pas adaptés aux spécificités du domaine. Un des projets de recherche du Centre de recherche en géomatique (CRG) est de concevoir une famille d'outils AGL intégrés permettant d'assister le concepteur durant certaines étapes du développement d'un SIRS. Ces outils s'inscrivent dans le concept du génie de l'information (information engineering) qui préconise l'utilisation d'une méthode structurée de développement, une approche par les données, et l'utilisation maximale d'outils AGL (Bédard 1989). Nous présentons un de ces outils qui assistera le concepteur lors de la modélisation conceptuelle des données d'une application à référence spatiale. Nous définissons les caractéristiques que doit contenir un outil AGL de modélisation de données adapté au développement des SIRS. Il en résulte une extension aux outils AGL de modélisation générique déjà existants, ou en d'autres termes, un outil spécialisé pour les SIRS.

En un premier temps, nous abordons la pertinence de l'utilisation de tels outils lors du développement de SIRS, ensuite nous énonçons les principales fonctions que doit contenir un outil AGL pour la modélisation conceptuelle des données. Finalement, nous discutons des fonctions que contiendra l'outil de modélisation adapté au contexte de développement de SIRS et nous terminons avec quelques exemples de l'interface à l'usager d'un prototype en développement au CRG.

2. L'UTILISATION D'OUTILS AGL DANS LE DÉVELOPPEMENT DES SIRS

Un outil AGL assiste le concepteur et le programmeur dans les différentes phases de développement d'un système d'information. Carma McClure (1988) définit la technologie CASE comme suit:

> *"CASE technology is the automation of step-by-step methodologies for software and systems development from step-one planning to ongoing maintenance; it is designed to automate the drugery of development and free the developper to solve problems."*

Les outils AGL permettent aux développeurs de passer plus de temps à résoudre les problèmes reliés à l'application et à passer moins de temps à effectuer les différents diagrammes qu'implique l'application d'une méthode structurée de développement. L'utilisation des outils AGL a donc donné un regain de popularité aux méthodes structurées. L'utilisation d'une famille d'outils AGL intégrés est encore plus intéressante parce qu'elle permet de réutiliser le résultat d'une étape antécédente à une étape subséquente du développement (Jones 1991).

L'utilisation de ces outils dans le développement de SIRS possède la même justification que pour le développement de SI traditionnels: obtenir tous les avantages de l'application d'une méthode structurée de développement avec des efforts moindres que par le passé. De plus, cette utilisation aide à "nourrir" le SGRG (Système de Gestion des Ressources

Géomatiques) qui est un IRDS (Information Ressources Dictionnary System) adapté aux SIRS et jumelé à un atlas électronique (Dickey et al, 1992).

3. UN AXE DE RECHERCHE EN DÉVELOPPEMENT DE SIRS

L'axe de recherche dans lequel s'inscrit la conception de l'outil de modélisation vise à définir les caractéristiques inhérentes au développement des SIRS pour ensuite concevoir une famille d'outils AGL adaptés aux SIRS. Nous croyons que lors du développement de SIRS, il sera plus efficace d'utiliser des outils AGL spécialisés au domaine de la géomatique plutôt que des outils AGL génériques tels que retrouvés sur le marché.

Avec l'outil d'inventaire et d'analyse des données à référence spatiale développé au CRG, les données cartographiques disponibles dans l'organisation sont inventoriées. Ces résultats peuvent, par la suite, être récupérés par l'outil de modélisation conceptuelle des données. Les données de l'inventaire servent également à l'analyse de l'intégration des données cartographiques. Lors de cette analyse, on tient compte des systèmes sources de données (information provenant de l'inventaire) et du système cible défini dans le modèle conceptuel de données (MCD). On y détermine les sources des données du système cible. Cette information sera par la suite réinjectée dans le dictionnaire de données. On doit donc prévoir, dans l'outil de modélisation, des "procédures" afin de rendre accessible cette information. Également, l'outil de modélisation pourra générer automatiquement une structure logique préliminaire en un formalisme de niveau logique propre à chaque technologie utilisée (logiciels GIS, CAD, SGBD, etc). Cette structure sera, par la suite, récupérée dans un outil de modélisation logique qui permettra d'effectuer certaines optimisations pour la structure de données (ex. ADMINISTRATOR de TIGRIS) (figure 1).

Actuellement, l'outil d'inventaire et d'analyse, l'outil de symbologie sont en développement. Les outils de modélisation conceptuelle, l'outil d'intégration des données et le SGRG sont en phase de conception (Bédard et al 1991). La conception de l'outil de prototypage débutera au printemps.

4. LES QUALITÉS ET LES FONCTIONS PARTICULIÈRES D'UN BON OUTIL DE MODÉLISATION.

L'outil de modélisation de données n'est pas seulement un logiciel de dessin avec des facilités aidant à la création de modèles de données; tout en créant le modèle, la signification de ce modèle est emmagasinée car ce n'est pas le schéma qui importe mais bien ce qu'il représente (Martin 1990). Un bon outil de modélisation emmagasinera cette signification de sorte qu'elle puisse être accessible et réutilisable aux étapes subséquentes du développement du SI. Par exemple, du modèle conceptuel de données, nous pourrons récupérer la signification du schéma et du dictionnaire de données afin de les réutiliser pour générer un modèle logique de données préliminaire.

L'outil doit, à la fois, faciliter la création du modèle de données tout en permettant d'augmenter la richesse de celui-ci. Ainsi, un bon outil de modélisation emploiera un formalisme pour la création des modèles de données qui est précis et dont l'intégrité peut être vérifiée de manière informatique.

A la lumière des recommandations de différents auteurs (Martin 1990, McClure 1988, Olle 1991), nous avons établi une liste de caractéristiques que doit posséder un bon outil de modélisation de données. Cette liste présente des caractéristiques qui sont particulièrement intéressantes pour la conception d'un outil adapté à la référence spatiale.

Caractéristiques d'un bon outil CASE de modélisation de données:

- L'usager doit être capable de naviguer facilement à travers un modèle complexe, changer la représentation, avec des techniques telles que PAGE, SCROOL, ZOOM, SHOW...;
- Un usager doit être capable de trouver une information avec une recherche minimale. Des informations intimement reliées doivent être près l'une de l'autre sur le modèle, ce qui minimise la navigation à l'écran;
- Permettre différentes vues du modèle de données, i.e. une représentation des données telle que perçue par une personne, un service, une application. La vue présente seulement les éléments d'intérêt pour un usager à un moment précis;
- Une simple vue d'ensemble du modèle doit être décomposable en des niveaux de détails successifs. Lorsque c'est possible, le diagramme détaillé doit avoir la même forme qu'à un niveau plus élevé;
- Solliciter l'utilisateur lors de la création des entités et des relations afin de créer le dictionnaire de données en même temps que le modèle;
- Emmagasiner la signification du schéma dans un IRDS, en plus du schéma lui-même;
- Normaliser le modèle de données;
- Convertir automatiquement, autant que possible, les modèles d'un à l'autre;
- Coordonner l'information sur plusieurs modèles et vérifier s'ils sont complets, intègres et consistents;
- Générer automatiquement la documentation (dictionnaire des données) dans un format prédéfini;
- Lorsqu'il survient des changements au système d'information, ces changements devraient se refléter dans les modèles car ceux-ci deviennent la documentation du système.

5. LES FONCTIONS À AJOUTER POUR UN OUTIL DE MODÉLISATION ADAPTÉ AUX SIRS

Une des étapes importantes de la conception de l'outil de modélisation des données adapté aux SIRS était d'évaluer les formalismes de modélisation existants et d'identifier les améliorations à apporter afin d'obtenir un formalisme tenant compte des préoccupations propres au développement des SIRS. Ceci fut l'objet de recherches au CRG (Bédard et al 1989, Caron 1991) et il s'agissait de cerner les lacunes qui persistent dans l'utilisation des formalismes existants face aux problèmes reliés à la modélisation des applications SIRS, pour ensuite apporter des éléments de solutions.

Les problèmes majeurs qui ont été identifiés concernent la modélisation de la référence spatiale, de la référence temporelle ainsi que la complexité des modèles rencontrés dans nos applications. Pour résoudre ces problèmes, Caron et Bédard (1992) proposent un nouveau formalisme, appelé MODUL-R. Ce dernier se compose du formalisme entité-relation (dialecte individuel) auquel se greffent plusieurs modules qui apportent des

solutions aux problèmes mentionnés plus tôt. Lors de la modélisation d'un projet avec ce formalisme, seuls les modules nécessaires à l'application peuvent être utilisés. Parmi les solutions apportées par MODUL-R, certaines sont directement liées à l'utilisation de ce formalisme pour la modélisation d'un SIRS et ne pourraient pas être utilisées dans un autre contexte. Cependant, les autres solutions, bien qu'elles soient applicables pour le développement de SI traditionnels, ont été conçues pour résoudre une problématique qui est présente dans les SIRS.

L'outil de modélisation des données à référence spatiale a été conçu afin d'utiliser les solutions apportées par MODUL-R. Egalement, lors de la conception de l'outil de modélisation, nous avions le souci de créer une famille d'outils AGL intégrés adaptés à la référence spatiale (figure 1). Ces outils intégrés permettent de récupérer l'effort déjà investi à une étape subséquente du développement d'un SIRS. Parallèlement à l'outil de modélisation, nous développons également des outils permettant de faire l'inventaire des données cartographiques ainsi que l'intégration de ces données. Des liens entre ces outils et l'outil de modélisation permettront de récupérer et utiliser les données recueillies. De plus, la perspective de traduire les données du modèle conceptuel de données en des modèles logiques de données supportant des technologies utilisées en SIRS est intéressante.

L'outil de modélisation possède des caractéristiques qui sont propres à la modélisation de SIRS et d'autres qui sont applicables à la modélisation de SI traditionnels. Le premier ensemble de caractéristiques pourraient facilement être intégré à un outil AGL déjà existant afin de l'adapter à la modélisation de SIRS.

5.1 Caractéristiques propres à la modélisation de SIRS.

L'outil de modélisation à référence spatiale doit posséder des fonction pour:

- la modélisation de la référence spatiale;
- la création d'un dictionnaire de données cartographiques qui définit les attributs cartographiques des entités (ex. forme géométrique exacte, symbologie de base);
- l'établissement d'un lien avec l'outil d'inventaire des données cartographiques;
- l'établissement d'un lien avec l'outil d'intégration des données cartographiques;
- la traduction du modèle conceptuel de données vers des modèles logiques de données supportant des technologies utilisées dans le domaine des SIRS.

Modélisation de la référence spatiale

L'outil possède des fonctions permettant d'attacher à une entité un pictogramme qui représente la forme que l'on désire donner à cette entité (figure 4). Ces pictogrammes sont conformes à ce qui est décrit dans MODUL-R, i.e. qu'il existe les pictogrammes de base POINT, LIGNE, SURFACE, VOLUME. Ces pictogrammes de base peuvent être utilisés de façon alternative pour une entité particulière. Par exemple, sur une carte à échelle moyenne, un verger pourra être représenté par un point lorsque sa superficie est plus petite que 1 hectare et par une surface lorsqu'elle est plus grande. Ces pictogrammes incluent également la possibilité d'agrégations spatiales. Lors de la consultation des données de l'inventaire, les formes des entités sont accessibles.

Création d'un dictionnaire de données cartographiques

L'outil possède des fonctions afin de compléter le dictionnaire de données cartographiques. Ce dernier comprend des informations sur les attributs cartographiques des objets (ex.: forme géométrique exacte, règles d'agrégation spatiale, symbologie de base). Egalement, le dictionnaire de données cartographiques indique s'il existe des entités cartographiées qui ne sont dans l'application qu'à titre d'information de contexte (ex.: courbes de niveaux). L'outil possède également des fonctions permettant d'imprimer ce document dans un format prédéfini (tout comme le dictionnaire de données). Le dictionnaire de données de la Base Nationale de Données Topographiques (Bédard 1990) constitue un bel exemple de dictionnaire de données cartographiques pour le niveau conceptuel.

Lien avec l'outil d'inventaire des données cartographiques

Les données provenant de l'inventaire pourront être importées dans l'outil de modélisation. Lors de l'import des données, un ménage s'effectue afin d'éliminer les problèmes de redondance entre les différentes collections de documents. Ainsi, lors de la création du MCD, nous pouvons sélectionner les données ou leurs caractéristiques à partir des données de l'inventaire. Ces données peuvent être accessibles en tout temps lors de la création du schéma. Lors de la création des entités, nous consultons la liste des entités répertoriées dans l'inventaire. De cette liste, nous consultons la définition et la description géométrique rattachée à cette entité dans l'inventaire. Tout au long de cette consultation, le modélisateur peut sélectionner les éléments qui l'intéressent. De la même façon, pour la création des attributs d'une entité, nous pouvons consulter la liste des entités provenant de l'inventaire, sélectionner une entité et consulter la liste de ses attributs et ensuite consulter le détail conçernant cet attribut.

Lien avec l'outil d'intégration des données cartographiques

Les données de l'inventaire sont également utilisées lors de l'analyse d'intégration des données. A cet étape, nous déterminons les sources de nos données en fonction de notre système cible, défini dans le MCD. L'outil de modélisation doit donc contenir une fonction d'exportation dans un format compatible avec l'outil d'intégration des données.

Au sortir de l'outil d'intégration, nous possédons une base de données sur les sources de nos informations: le dictionnaire des méta-données. Ce dernier est réinjecté dans l'outil de modélisation afin de compléter le dictionnaire de données et aussi pour connaître de façon rapide la provenance de nos données à référence spatiale. De plus, lors de la traduction vers des modèles logiques, ces informations pourront être réutilisées afin de générer un guide de numérisation des données ainsi que des procédures pour l'entrée des données descriptives.

Le MCD devenant une partie importante de la documentation d'un système, des fonctions de consultations des méta-données sont prévues à l'intérieur de l'outil de modélisation. Nous pouvons donc interactivement connaître la source des attributs descriptifs des entités en pointant sur l'attribut dans le schéma. Nous pouvons consulter la source des attributs géométriques des entités (position, forme,...) en pointant sur son pictogramme

spatial. Lorsqu'une entité possède une représentation spatiale alternative, nous pouvons consulter la source de ces deux représentation différentes.

Traduction vers des modèles logiques supportant des technologies utilisées en SIRS

Un des principaux avantages de la technologie AGL, c'est la possibilité de récupérer le travail déjà effectué à une étape subséquente. A partir du MCD et du dictionnaire des données construits dans l'outil de modélisation, nous pouvons effectuer une traduction vers des formalismes de niveau logique pour ainsi récupérer les efforts investis au niveau conceptuel. Nous avons développé des algorithmes permettant de faire une première traduction d'un modèle utilisant le formalisme MODUL-R vers la technologie TIGRIS de Intergraph ainsi que vers un SGBD relationnel. Cette traduction se fera de façon automatique et il ne restera qu'à optimiser la structure de données. Il nous reste à développer un algorithme permettant de traduire la référence spatiale des entités décrites au MCD vers un logiciel qui sera couplé à un SGBD relationnel.

Traduction vers la technologie TIGRIS de Intergraph

Dans l'environnement TIGRIS, un GIS orienté-objet, il existe le module ADMINISTRATOR qui permet de définir la structure de l'application grâce à un modèle de niveau logique. A l'aide de ce modèle, nous établissons les éléments qui sont cartographiés (nommés "base features") ainsi que leur forme, puis ceux qui ne le sont pas ("complex feature"), les attributs de ces éléments, et les liens entre ces éléments (figure 3). L'outil de modélisation contient un algorithme qui traduit, sans optimisation, un MCD construit avec notre outil en un schéma ADMINISTRATOR.

Traduction vers un modèle logique relationnel

Un algorithme effectuant la traduction, sans optimisation, d'un modèle utilisant MODUL-R vers un modèle logique relationnel a été développé. Le modèle logique relationnel pourra se présenter sous une forme graphique ou textuelle. A ceci, sera couplé un autre algorithme qui traduira l'aspect cartographique des données présentes dans le MCD. Cet algorithme sera développé dans les prochains mois.

5.2 Caractéristiques applicables à la modélisation de SIRS et de SI

MODUL-R apporte également d'autres solutions qui ne sont pas exclusives à la problématique de la modélisation de SIRS mais qui sont intéressantes.

Pour concevoir l'outil de modélisation de données, nous utilisons également les solutions apportées par MODUL-R aux problèmes qui ne sont pas exclusifs à la modélistion à référence spatiale mais bien à la modélisation en général. Ces problèmes sont la modélisation de la référence temporelle ainsi que la modélisation complexe. Conformément à ce formalisme, l'outil se présente sous une forme modulaire où l'utilisateur sélectionne les composantes qui sont pertinentes à son projet. L'outil possède des fonctions permettant d'appliquer ces solutions. L'utilisateur choisira les solutions qu'il veut utiliser en sélectionnant des extensions qui regroupent des ensembles de fonctions (figure 2). Nous vous présentons brièvement les fonctions qui se rattachent aux différentes extensions de l'outil.

Extension **Référence temporelle**

Utilisation des pictogrammes temporels.

Lors de la création des entités, des attributs et des relations, les fonctions pour l'ajout d'un pictogramme temporel sont présentes. Ils permettent d'exprimer le désir de gérer soit le présent seulement, ou inclure le passé ou les futurs possibles d'une entité, ou d'une relation que ce soit pour son existence ou l'évolution des valeurs de leurs attributs.

Extension **Abstraction**

Ajout des fonctions de vues et de niveaux d'abstraction

Le choix de cette extension implique un ensemble de fonctions permettant de manipuler la représentation du modèle. Les fonctions suivantes sont alors disponibles:

Cinq niveaux de détails permettent de visualiser le modèle avec une vision de plus en plus globale;
Une fonction permettant de regrouper les éléments d'un même modèle sous un thème;
Une fonction permettant à l'utilisateur de visualiser le modèle avec les éléments qui l'intéressent, c'est-à-dire que l'utilisateur sélectionne les différentes composantes qui seront présentes sur son modèle.

Extension **Généralisation**

Ajout des fonctions permettant la création de super-entités.

Une fonction permettant de regrouper des entités possédant des attributs communs ou des relations communes en une entité virtuelle, la super-entité, afin de simplifier la lecture du modèle.

Extension **Agrégation**

Ajout des fonctions permettant la création d'agrégations sémantiques telles qu'on les retrouve dans les nouveaux standards E/R et dans la modélisation orientée-objet (incluant la notion d'héritage). Cette extension couvre également les agrégations spatiales.

6. PRÉSENTATION DU PROTOTYPE D'OUTIL AGL DE MODÉLISATION EN DÉVELOPEMENT AU CRG

Nous travaillons présentement à l'élaboration d'un premier prototype de l'outil de modélisation. La création de ce prototype vise essentiellement à montrer de façon interactive les composantes que devra contenir l'outil. La figure 4 présente un formulaire permettant de créer une entité et d'y rattacher le pictogramme spatial approprié. La création du dictionnaire des données d'effectue en même temps que la création du schéma. La figure 5 présente un formulaire permettant de créer une relation entre deux entités.

7. CONCLUSION

Nous avons étudié ce que doit contenir un outil de modélisation de données à référence spatiale. Nous avons développé le formalisme MODUL-R qui sert à l'outil de modélisation. L'outil ajoute donc certaines composantes au formalisme de base Entité-Relation. Nous avons défini un algorithme permettant de traduire un modèle conceptuel de données utilisant une ou plusieurs extensions de MODUL-R vers un modèle ADMINISTRATOR de l'environnement TIGRIS de Intergraph. Egalement, nous développons des algorithmes permettant de traduire un modèle conceptuel utilisant MODUL-R vers un modèle logique de données relationnel couplé à un logiciel de cartographie numérique (MGE Intergraph). Les prochains développements permettront de rafiner l'interface à l'usager et de compléter la liste des adaptations nécessaires aux SIRS.

8. REMERCIEMENTS

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9. REFERENCES

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FIGURES

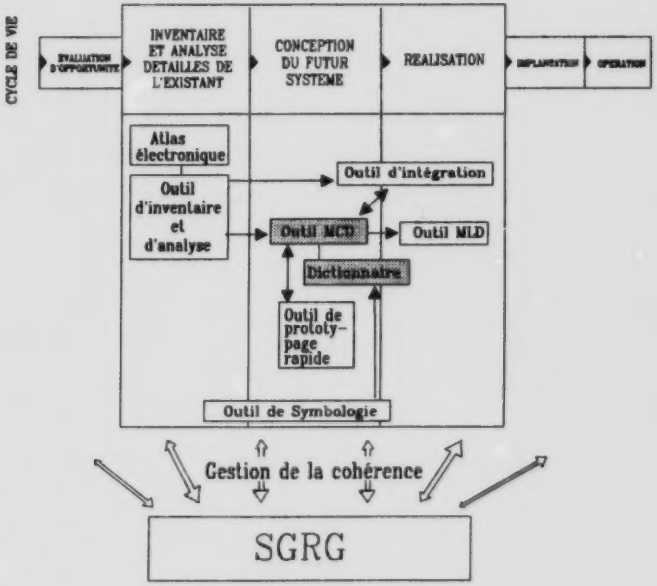

Figure 1: L'outil de modélisation et l'axe de recherche en développement de SIRS au CRG.

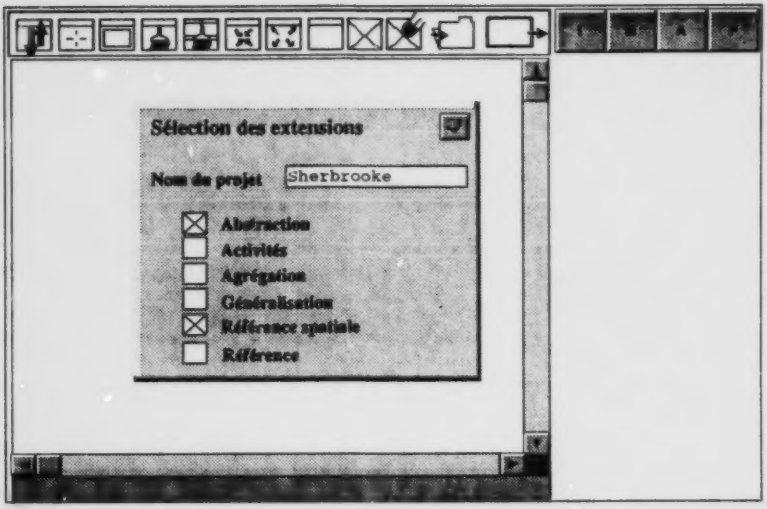

Figure 2: Sélection des extensions à utiliser pour modéliser un projet donné.

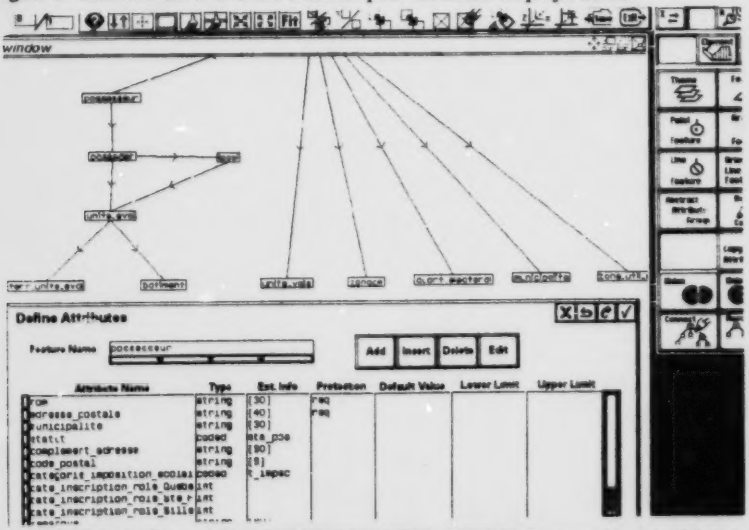

Figure 3: Extrait d'un schéma ADMINISTRATOR (TIGRIS Intergraph) qui définit la structure de données d'une application.

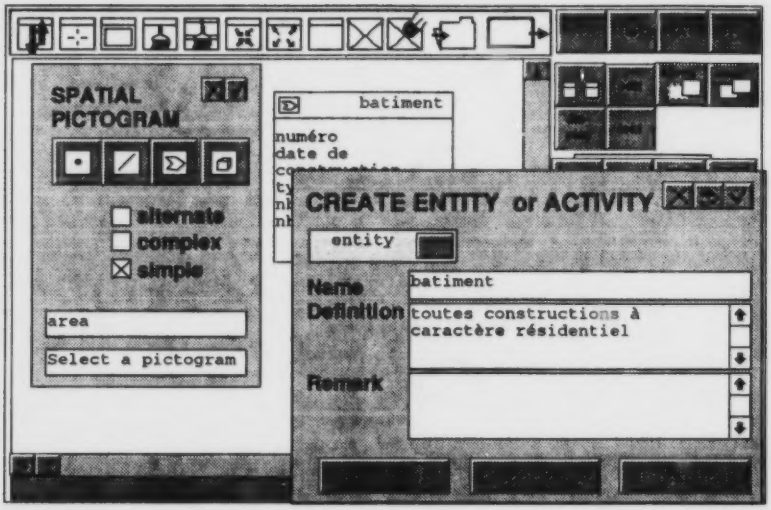

Figure 4: Formulaire de création d'une entité et de son pictogramme spatial.

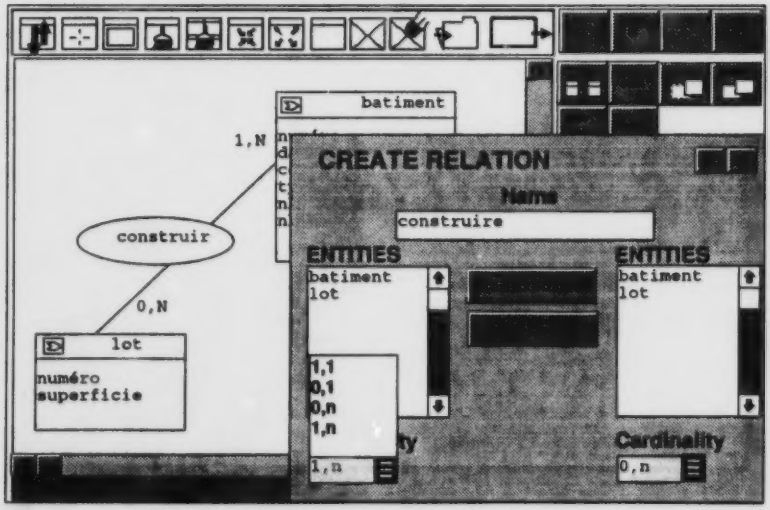

Figure 5: Formulaire de création d'une relation.

La gestion du temps dans les GIS : certains concepts fondamentaux

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Résumé

La gestion du temps dans les GIS est une problématique en effervescence et les recherches actuelles devraient permettre à moyen terme, de converger vers des solutions efficaces à l'intégration du temps aux bases de données à référence spatiale actuelles (statiques). Afin d'y parvenir, une bonne compréhension du temps lui-même s'impose ainsi que son effet sur la référence spatiale. On explique donc comment la temporalité s'exprime sur les entités, sur leur existence et leur évolution dans l'espace. L'approche adoptée s'inspire de concepts développés dans les recherches sur la référence spatiale en transposant différentes notions de ces dernières à la référence temporelle. Ce document devrait donc permettre aux utilisateurs et concepteurs de GIS de mieux comprendre la combinaison espace-temps dans laquelle évoluent nos données.

Time management in GIS : some basic concepts

Abstract

A new issue in GIS research is to effectively manage the temporal aspect of geographic phenomena. The integration of time with spatial databases should become more efficient with the ongoing researches. The first step is to get a good comprehension of time itself and its effect on spatial reference. The authors discuss about the impact of time on the entities, their existence and their evolution in space. The aproach makes use of spatial reference concepts to develop different concepts related to the temporal reference. The content of this paper should allow GIS users and GIS designers to better understand the space-time combination in which data evolve.

1. INTRODUCTION

La prise en compte du temps dans les systèmes d'information à référence spatiale (SIRS) est un complément important aux données à référence spatiale. Afin d'arriver à intégrer puis à gérer cette composante de la réalité à l'intérieur de logiciels GIS (Geographic Information System), il est primordial de définir les concepts fondamentaux de l'espace et du temps ainsi que l'influence de ce dernier sur le premier. Le présent document présente l'état actuel de nos travaux pour décrire plusieurs concepts de base. Nous commençons par la structure et l'organisation de la gestion du temps, pour ensuite expliquer les notions d'existence et d'évolution, puis terminer en définissant les variables nécessaires à la gestion du comportement des entités spatiales dans le temps.

2. IMPORTANCE DU TEMPS DANS LES SIRS.

Fondamentalement, à part les fonctions de saisie, de conservation et de traitement des données, le but principal d'un SIRS est de fournir l'information demandée par l'utilisateur afin de bien orienter ses prises de décision. En effet, l'information intervient à divers niveaux dans un processus de décision; plus elle sera complète, meilleure seront les chances d'une bonne prise de décision. Nutt (1989) identifie d'ailleurs la richesse de l'information comme l'un des deux facteurs caractérisant une décision, l'autre étant le degré de structuration des procédures de traitement. C'est principalement à l'intérieur de ce premier facteur que l'aspect temporel intervient. Utiliser l'information actuelle en tenant compte de ce qu'elle a été (états passés, historique) et de ce qu'elle est susceptible de devenir (par simulation ou par extrapolation) a pour conséquence de l'enrichir et donc d'améliorer sa contribution à un processus de décision bien orienté et bien structuré. De plus, si le logiciel GIS utilisé pouvait permettre de gérer et de visualiser de façon dynamique ou animée l'évolution des données dans l'espace et le temps, le message serait plus évident et plus facile à comprendre. Armenakis (1991) mentionne que la visualisation aide à l'analyse des données et à la compréhension des processus. L'ajout d'un outil, permettant la visualisation, aux GIS actuels passe avant tout par l'intégration de la temporalité car tout changement, qu'il soit spatial (mouvement) ou non, doit faire appel à des considérations temporelles.

3. LE TEMPS

Du point de vue philosophique, on admet qu'il existe trois théories sur le temps: la théorie idéaliste, la théorie réaliste et la théorie relationnelle (Zwart 1975). Chacune d'elle a une perception différente de la nature du temps mais les trois s'entendent tout de même sur certains points. Kant (1787), un partisan modéré de la théorie idéaliste, soutient plusieurs choses susceptibles de nous intéresser.

Il admet d'abord que le temps, au même titre que l'espace, est une source d'où l'on tire diverses connaissances synthétiques. Si nous convenons d'entendre connaissances synthétiques par modèles, on doit donc conclure que nous pouvons modéliser les choses qui nous entourent à partir de l'espace et du temps. Structurellement, Kant convient d'un univers temporel uni-dimensionnel, c'est-à-dire d'une organisation linéaire du temps. Toutefois, pour nous représenter le temps, nous nous dissocierons quelque peu de Kant et de la théorie idéaliste pour se rapprocher de la théorie réaliste. Cette théorie élaborée par Newton perçoit le temps comme un flux dans lequel nous sommes transportés et sur lequel nous ne pouvons exercer aucun contrôle. Il s'écoule dans une seule direction et nous ne pouvons physiquement y déroger.

Cette théorie nous permet ainsi de représenter le flux temporel par une droite orientée vers la droite (figure 1). Les éléments temporels apparaissent sur cette droite comme des points (instants) et des lignes (durées) qui définissent l'existence et l'évolution des entités. De là, si nous considérons les instants et durés comme des objets 0-D et 1D dans un espace 1-D, nous pouvons tirer profit des recherches existantes en référence spatiale. C'est cette approche que nous avons utilisée pour mieux comprendre les composantes du temps.

Pour revenir à Kant, concernant la manière dont le temps agit sur les entités, il déclare que ce n'est pas le temps lui-même qui change mais quelque chose qui est dans le temps. On perçoit donc les choses et la succession de leurs états. Cette affirmation nous amène à comprendre que nous percevons les choses en admettant leur existence et que nous concevons la succession de leurs états en constatant leur évolution. En langage de base de données, nous pouvons dire que l'existence s'adresse directement à l'entité ou à la relation tandis que l'évolution s'exprime via les valeurs d'attributs qui changent tant pour l'entité que pour la relation. Ces deux concepts, existence et évolution, sont les deux

éléments de changements qui vont nous permettre de modéliser l'action du temps sur les entités et les relations.

4. EXISTENCE ET ÉVOLUTION

4.1. EXISTENCE

On entend par existence le fait qu'un phénomènede la réalité (personne, objet, événement, concept), soit perceptible à nos sens ou à notre esprit. L'existence d'une entité est déterminée par sa "naissance" et par sa "mort". Toutefois, il est important de définir deux caractéristiques d'existence à gérer à l'intérieur des SIRS : la présence effective et le degré d'activation.

Durant son existence, une entité ou une relation à l'intérieur d'un SIRS, peut être active ou inactive. Pour illustrer ce fait, pensons au cas d'une patinoire qu'on monte à chaque automne et qu'on démonte à chaque printemps. Elle devient donc active à l'automne et inactive au printemps mais conserve quand même toujours une présence effective dans la base de données jusqu'à ce qu'on la démonte définitivement pour faire place, par exemple, à un développement domiciliaire.

Dans une base de données, cette notion d'existence concerne exclusivement l'entité ou la relation. Toutefois elle peut aussi dépendre indirectement des attributs car les changements dans les valeurs d'attributs peuvent être assez importants pour qu'ils entraînent une profonde transformation de l'entité ou de la relation, provoquant alors sa mort et redéfinissant une nouvelle entité ou une nouvelle relation.

4.2. ÉVOLUTION

Newton-Smith (1980) reconnaît qu'un changement affectant un objet est constitué par l'altération de ses propriétés. Bilodeau et al. (1990) soutiennent que l'évolution d'une entité se reflète par les changements de la valeur d'un ou de plusieurs attributs. Donc, dans le temps, les propriétés géométriques (la référence spatiale), graphiques (poids, style de ligne, couleur etc...) et descriptives d'une entité ou d'une relation changent, et différents paramètres peuvent caractériser cette évolution.

a) instantanée / graduelle : Si nous définissons la résolution temporelle de l'échelle de mesure utilisée comme étant la plus petite subdivision sur cette échelle (et parfois propre à chaque entité ou relation) et que la durée de l'évolution d'une entité ou d'une relation est inférieure ou égale à cette subdivision, nous parlerons d'évolution instantanée. D'un autre côté, si la durée de l'évolution s'étend au-delà de la résolution temporelle, il sera alors question d'évolution graduelle.

b) déterminée / indéterminée : L'incertitude relative à l'évolution d'une entité ou d'une relation nous amène à parler de "déterminée / indéterminée". C'est-à-dire qu'on peut préciser ou non quand l'évolution d'une entité ou d'une relation commence (date de début) et quand elle finit (date de fin). Cette notion s'applique aussi bien à l'existence pour laquelle on peut préciser ou non sa "date de naissance" et sa "date de mort". Selon notre position temporelle (avant, pendant ou après l'évolution ou l'existence de l'entité ou de la relation) nous parlerons de début et de fin (d'évolution) et de naissance et de mort (de l'existence) connus, inconnus, prévisibles ou imprévisibles.

Ces notions d'existence et d'évolution appliquées aux entités et aux relations spatiales et non-spatiales nous amènent donc à parler d'entités temporelles et de relations temporelles.

On peut définir l'entité temporelle comme étant une composante d'un modèle conceptuel de données qui correspond à un élément fondamental nécessaire pour obtenir l'information sur l'existence et l'évolution des entités spatiales, non-spatiales et géométriques.

Comme les relations spatiales qui représentent la connectivité spatiale entre les entités géométriques (point, ligne, polygone, etc...), les relations temporelles représentent la connectivité temporelle entre les entités temporelles (instant et durée). Ces deux types de relation permettent de déduire les relations spatiales et temporelles entre les entités gérées dans la base de données à référence spatiale. Elles complètent les relations sémantiques.

5. L'ESPACE-TEMPS

Si on dit des GIS actuels qu'ils sont statiques, c'est parce qu'ils ne peuvent gérer facilement les changements des propriétés descriptives des entités et surtout qu'ils ne peuvent représenter dynamiquement les variations et les transformations de la référence

spatiale. Nous disons bien "facilement" car il est malgré tout possible d'y arriver en s'inspirant de différents modèles de bases de données élaborés entre autres par Snodgrass et Ahn (1985). Ces modèles s'appuient principalement sur l'utilisation de "clichés" (snapshots) des états de notre bases de données dans la perspective de deux types de temps utilisés : le temps base de données (transaction time) et le temps effectif (valid time). La véritable solution s'avère toutefois plus complexe quand vient le temps de transposer ces modèles aux bases de données à référence spatiale (BDRS). Un constat déjà fait par Armstrong (1988). Si nous commençons d'abord par bien comprendre l'espace-temps et le comportement des entités spatiales à l'intérieur de celui-ci, nous pourrons élaborer des solutions efficaces applicables aux BDRS.

Incorporées l'une avec l'autre, les notions d'espace et de temps engendrent celle du mouvement. La théorie de la relativité d'Einstein pour décrire le mouvement des corps célestes et des corps atomiques amena une toute nouvelle perception de l'espace et du temps. Toutefois, dans l'univers terrestre où nous travaillons et que nous modélisons généralement dans les SIRS, tout les mouvements sont faibles (c'est-à-dire v/c << 1). Les principes de la mécanique Newtonienne s'y appliquent et ce sont eux aujourd'hui que nous utilisons.

Pour bien saisir comment tout les aspects de la référence spatiale peuvent changer et ce que cela implique, nous considérerons trois situations : le cas de une entité, le cas de deux entités et le cas de n entités (une population d'entités).

5.1. UNE ENTITÉ

Les variables de base de la référence spatiale d'une entité sont *la position, la forme, la taille et l'orientation* (Chevallier et Bédard 1991). C'est donc via une ou plusieurs de ces variables qui sont exprimés par les attributs géométriques (ex. : x,y, rayon d'un arc) des entités géométriques (point, ligne, etc...) que la référence spatiale d'une entité changera.

La figure 2 montre des exemples de chaque cas où une entité, entre deux instants donnés t_1 et t_2, subit des transformations. Étant donné que ce sont les attributs géométriques de l'objet qui changent, c'est donc, comme nous l'avons défini, une évolution et elle peut être instantanée ou graduelle, déterminée ou indéterminée.

5.2. DEUX ENTITÉS

Entre deux entités, ce que nous voulons connaître, ce sont les relations spatiales qui les unissent. Champoux (1991), en s'inspirant de travaux antérieurs tels que ceux de Pullar (1988) et Egenhofer et Herring (1990), définit *onze relations spatiales* possibles entre deux entités, et chaque modification d'une ou de plusieurs variables de la référence spatiale de l'une ou des deux entités est susceptible de remanier la relation (figure 3). L'évolution de ces relations spatiales doit donc passer par un changement dans la position, et/ou la forme, et/ou la taille et/ou l'orientation (figure 4).

5.3. N ENTITÉS (une population)

Parce qu'une population d'entités compte plusieurs individus, sa description spatiale est plus complexe. Bilodeau (1991) propose de nouveaux paramètres de la référence spatiale d'une population. *La position, la forme et l'orientation* demeurent, mais il établit une distinction en ce qui concerne la taille. Il distingue en effet *la taille cumulative* de la *taille de population*. La première, qui concerne les individus plus que la population, équivaut à la sommation de la taille, telle que définit pour une entité, de tous les individus. Mise en rapport avec le nombre d'individus, elle permet de connaître le taux de présence de la population, c'est-à-dire du nombre d'individus par rapport à leur propre superficie. *La taille de population* équivaut quant à elle à l'aire de distribution de la population. Mise en rapport avec le nombre d'individus, elle permet de connaître le taux d'occupation, c'est-à-dire de la densité des individus par rapport à l'aire de distribution. De plus, si on met en rapport la taille cumulative et la taille de population, nous obtenons la densité spatiale. En plus de cet ajout à la référence spatiale d'une population, on doit aussi décrire un autre paramètre : son *type de distribution*. Hagget (1973) en présente trois : distribution régulière, aléatoire ou groupée.

Toutes ces caractéristiques spatiales d'une population peuvent changer avec le temps et deux mécanismes ont la possibilité d'intervenir pour provoquer un changement. Il s'agit de naissances et/ou morts d'individus de la population et des variations de la référence spatiale individuelle des entités composant la population.

5.3.1. Naissances et/ou morts d'individus

L'ensemble des paramètres spatiaux d'une population peuvent varier si des individus naissent ou meurent dans la population (figure 5 et 6). On parler alors de dynamique d'existence des individus.

5.3.2. La référence spatiale individuelle

L'ensemble des paramètres spatiaux d'une population peuvent varier si ceux de la référence spatiale de chaque individu changent (figure 7). On parler alors de dynamique spatiale des individus.

7. CONCLUSION

En s'appuyant sur les concepts de la référence spatiale relatifs à une, deux et N entités, nous sommes parvenus à mieux comprendre l'évolution spatiale des entités dans le temps. Nous avons vu que pour plus d'une entité, le changement des relations spatiales et des paramètres de la référence spatiale d'une population passe toujours par un changement seul ou la plupart du temps combiné des paramètres de la référence spatiale de une ou de plusieurs entités. C'est en modélisant ces paramètres des entités spatiales que nous parviendrons à représenter à l'intérieur des bases de données les mouvements et les processus spatiaux qui pourront de plus être visualisés dynamiquement.

8. REMERCIEMENTS

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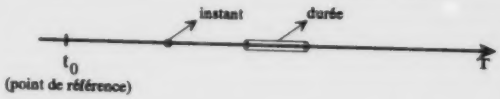

figure 1. Flux temporel

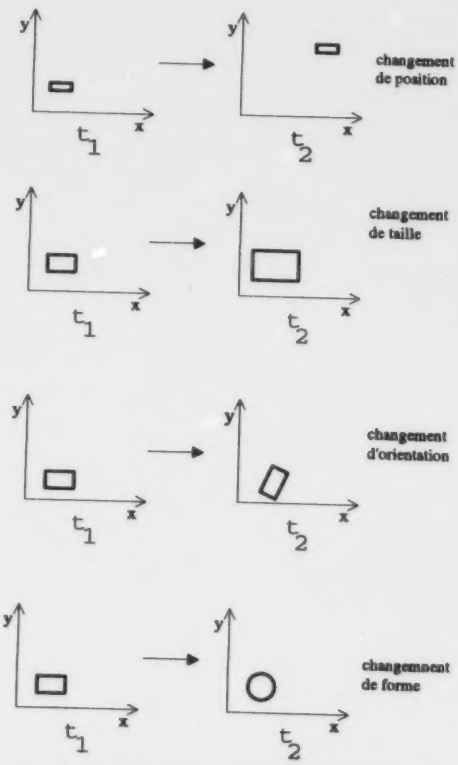

figure 2. Évolution de la référence spatiale d'un objet dans le temps

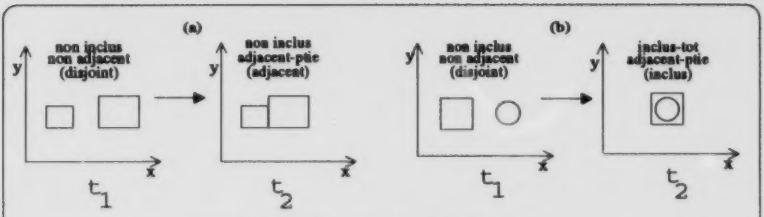

figure 3. Évolution des relations spatiales dans le temps

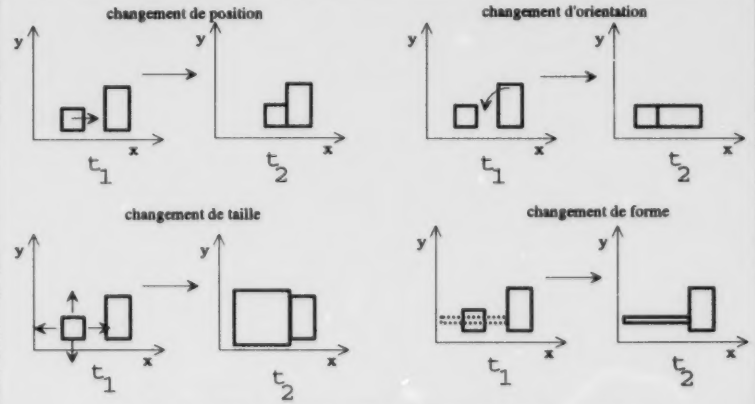

figure 4. Évolution des relations spatiales et les éléments de la référence spatiale.
(le cas de disjoint -> adjacent)

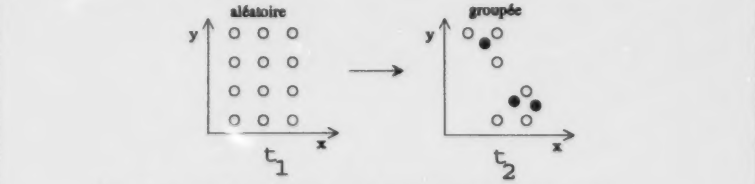

figure 5. Exemple de l'évolution du type de distribution d'une population par des naissances et/ou des morts d' individus. (cercles pleins = individus nés après t_1)

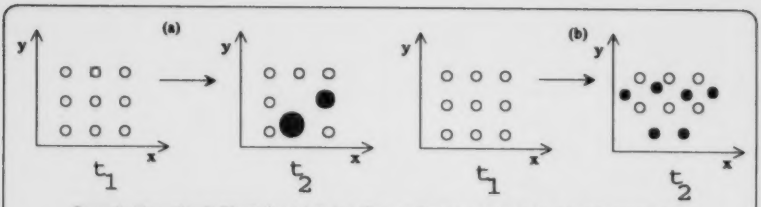

figure 6. Exemples de l'évolution (a) de la taille cumulative et (b) de la forme d'une population par des naissances et/ou des morts d' individus. (cercles pleins = individus nés après t_1)

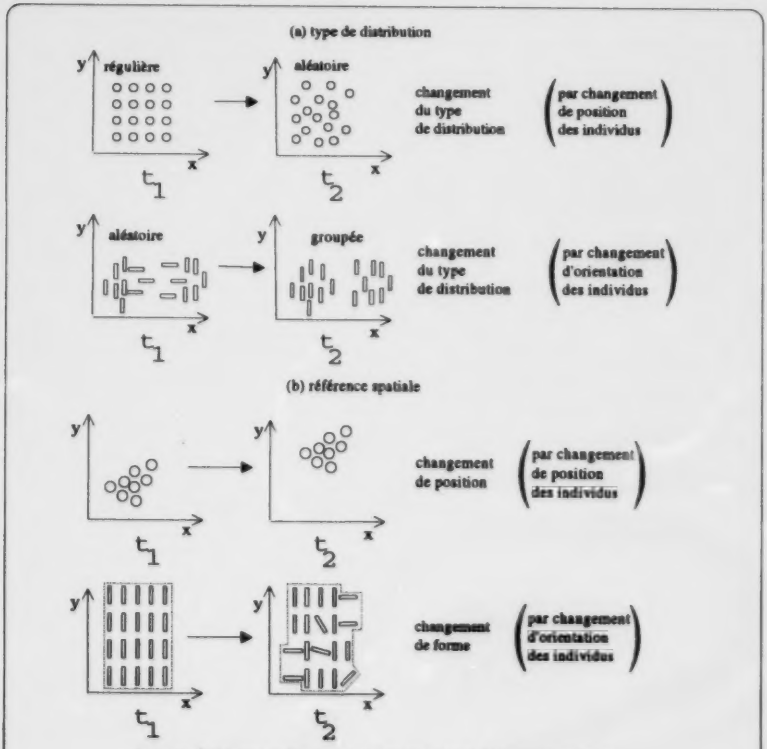

figure 7. Évolution du type de distribution (a) et de la référence spatiale (b) d'une population par le changement de la référence spatiale individuelle

Notions fondamentales d'analyse spatiale
Et son application sur 1,2 et plusieurs objets

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Résumé

Avec l'arrivé de la technologie SIG, on entend de plus en plus parler d'analyse spatiale. Ce terme est utilisé à gauche et à droite mais quand on tente de le définir, on se rend compte qu'il manque de notions scientifiques sur ce qu'est vraiment l'analyse spatiale. Le but de cet article est donc de palier en partie à ce manque de connaissance en présentant un ensemble d'éléments pour mieux cerner l'analyse spatiale. Nous commençons par proposer une définition de ce genre d'analyse, nous présentons par la suite une série d'opérateurs spatiaux qui permettent de réaliser ces analyses, puis nous appliquons ces notions à un objet (ex: caractéristiques spatiales d'une maison), deux objets (ex: relations spatiales entre deux maisons) et plusieurs objets (ex: distribution spatiale de 1000 maisons). Tout au long de la présentation des exemples et figures aideront à la compréhension des idées présentées. Ainsi les utilisateurs de SIG devraient être en mesure de mieux évaluer les possibilités de l'analyse spatiale.

Abstract

GIS technologies have given us a new expression that we use frequently: "Spatial analysis". Almost everybody in the GIS environment uses it. However, when we try to define what spatial analysis is, we find a lack of coherent and scientific notions. The goal of this presentation is to help us to gain a better understanding of these notions. The presentation will begin with a definition of spatial analysis, and a description of the spatial operators needed to conduct spatial analysis. After, we will apply these notions to one object (ex: spatial caracteristics of one house), two objects (ex: spatial relationship between two houses) and many objects (ex: spatial distribution of 1000 houses). During this presentation, many examples and illustrations will help to explain and demonstrate these notions. This presentation should benefit toGIS users so they better estimate the possibilities of spatial analysis.

DIGITIZING AT A SCALE OF 1:1

THE DEVELOPMENT OF A GIS DATA COLLECTION SYSTEM

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Abstract

This paper looks at the development of a system to provide data for a GIS using positional information obtained from the Global Positioning System (GPS) satellites. A brief description of GPS and the techniques for obtaining positions is given. The problems of collecting field data and some potential solutions are considered.

A description of the hardware/software component supplied by Acrostar follows. A lightweight GPS receiver and data-logger is used with user defined data notes and appropriate software. The software for differing accuracy requirements is also discussed.

The conversion software from GPS Latitudes and Longitudes to NAD27 UTM co-ordinates and then to GIS (TerraSoft) readable format is then described. This is written in BASIC and the reasons for using this particular language are commented on as well as the data processing and final input to the GIS.

The future potential of using GPS kinematic and high accuracy (phase measuring) methods to update databases is considered and discussed.

NUMÉRISATION À L'ÉCHELLE DE 1/1
ÉLABORATION D'UN SYSTÈME DE SAISIE DES DONNÉES DE SIG

RÉSUMÉ

Le présent article traite de l'élaboration d'un système de production de l'information pour un SIG qui utilise des données de position provenant des satellites du Système de positionnement global (SPG). Le SPG et les techniques d'établissement des positions sont décrits brièvement. Les problèmes de saisie des données de terrain et quelques solutions potentielles sont étudiés.

Suit une description du matériel/logiciel fourni par Acrostar. Un récepteur et un enregistreur de données de SPG légers sont utilisés avec les notes de l'utilisateur et le logiciel approprié. Le logiciel de distinction des exigences de précision est aussi analysé.

Le logiciel de conversion des latitudes et longitudes du SPG en coordonnées UTM, NAD27, puis en données assimilables par le SPG (TerraSoft) est ensuite décrit. Il est rédigé en BASIC et les raisons pour lesquelles ce langage particulier est utilisé sont commentées comme il en va du traitement des données et des entrées finales dans le SPG.

L'utilisation possible dans l'avenir de méthodes (de mesure de phase) cinématique très précises est étudiée.

INTRODUCTION

Only recently has any serious thought been given to the challenges facing GIS users when it comes to updating and maintaining their databases. This paper has been written to give an insight into the development of a system to combat this problem. As development is always on-going, the status of such a system will be improved and changed from the time of writing.

Hardcopy geographical databases, i.e. maps and plans, are outdated as soon as a new feature is added in the real world, making the map obsolete. Society may have grown used to this fact, but the reverse is true when dealing with computer data, as users generally expect that such information is up-to-date.

THE GLOBAL POSITIONING SYSTEM

Meeting the challenges of database maintenance can be time consuming and expensive in terms of manpower and equipment. Fortunately, GPS (Global Positioning System) fits the bill as an economical and accurate tool. GPS has been in the formative stages for some years, recently obtaining a surge of publicity in the 1991 military action against Kuwait when the Allied forces used it extensively to guide men and machines across the deserts.

GPS is a system of earth-orbiting satellites that continuously transmit their positions along with the exact time. When transmissions from four satellites are received simultaneously at a receiver anywhere on the earth's surface (or above it) then the receiver's position can be computed in three dimensions; latitude, longitude, and elevation. GPS receivers are passive, in that they only receive signals from satellites.

The system has been developed and is currently maintained by the Department of Defense in the United States. Although the initial applications were military, there are now many thousands of civilian users throughout the world, mainly in the surveying and navigation fields, who are putting the concepts of GPS to peaceful uses.

Positional accuracy when using GPS equipment can vary quite considerably, depending on the type and number of receivers and the techniques used to receive and process the incoming signals. Generally an absolute accuracy of somewhere between 5 metres and 50 metres can be obtained when using a single receiver. This accuracy is mainly dependent upon the satellite configuration (which is continuously changing as the satellites orbit around the earth) and is also affected by what is known as Selective Availability or SA for short.

The Defense Department (DoD) has the capability of intentionally degrading the signals from one or more of the satellites, which has the effect of decreasing single receiver accuracy. SA can be varied in intensity and is intended as a security measure to

presumably deprive potential military adversaries of high accuracy positioning. A very hot debate is currently is progress in the U.S. between DoD and other U.S.government agencies who favour ending SA. Support for the anti-SA side also comes from GPS equipment manufacturers and user groups.

SA was initiated on the 1st July 1991 and generally over the following months has been used at the lowest intensity with negligible effects. User groups, of course, hope that SA will be discontinued in the future.

The effects of SA can be nullified and accuracies improved to the 1-5 metre levels by using two (or more) receivers in what is called the differential mode. One receiver is used as a fixed base station and the other as a roving unit that carries out the actual survey data collection. Any signal degradation, intentional or not, is experienced at both receivers and a correction can be determined at the fixed base which is then applied to the rover. Any number of rovers can be used in conjunction with one base receiver.

Better accuracies can also be achieved in differential mode when the receiver measures the phase of the incoming satellite signal as well as using the data carried by it. Phase-measuring units, containing more hardware and requiring more software, are generally more expensive than normal receivers but the accuracies obtained rival and even improve upon those obtained by conventional survey methods without some of the hassles.
(cf. "GPS and the Total Station go Head-To-Head", Professional Surveyor July/August 1991)

One of the major requirements when collecting GPS data is that line of sight is available from the data points to the various satellites. In wooded areas this is not the problem that it might at first appear to be. As the satellite positions are continuously changing signals can be obtained through holes in the tree or bush canopy. Only in thick forested areas with little or no spaces between tree branches will the operator experience collection problems.

There are several ways of alleviating this blockage problem :

> One way is to get the antenna above the obstruction by raising it on light screw-together rods - this will obviously not be practical with large heights; another solution is to use a small balloon with the antenna mounted on the top - accuracy problems may occur here; yet another solution is to take an offset GPS position where no blockage exists and apply bearing and distance to the actual data point - various accuracies can be obtained depending on the level of sophistication when obtaining the bearing and distance.

Data collection problems may exist in the down-town areas of large cities and towns with many high-rise buildings providing blockages. Here the need for pre-operation planning is

paramount. By studying the forecasts of the satellite positions it is possible in most cases to obtain data when satellites are visible (on one side of a street, for example) with only minimal loss in accuracy due to unfavourable geometry.

THE ACROSTAR GEOLOGGER II

Descriptions of GPS receivers generally cite the number of channels in a particular receiver. As four satellites are required to obtain a position in X,Y and Z, receivers with less than four channels have to cycle between visible satellites with the probability of some data 'skewing'.

The Acrostar Geologger II receiver has six channels which allow it to track six satellites simultaneously. The field equipment consists of; a receiver weighing just under 3kg; a data logger, which is a sub notebook sized IBM-compatible MS-DOS computer weighing 1.25kg; and a small antenna that can be mounted on a range pole if desired. The power supply for the receiver allows more than 3 hours of continuous operation from an internal replaceable battery. 12 Volt 110/220V adaptors are also supplied. The batteries powering the data-logger allow more than 30 hours of use and can easily be replaced without data loss.

Operating temperatures range from around -10C to +50C for the data-logger. The receiver itself can withstand lower temperatures and if the data-logger could be kept reasonably warm (LCD screens can be affected at below 0C) then work could be undertaken in temperatures as low as -20C.

The two main units, receiver and logger can virtually fit on the palm of the hand or be carried in large pockets. However carrying cases with shoulder or waist straps are provided to allow for ease of use in the field.

Before going out in the field the operator should decide on names for the data features that are going to be collected. These features or 'entities' can be entered in the data-logger to form a menu that can be recalled in the field and then recorded in the logger along with the GPS position. It is also possible to form an entity menu 'on the fly' in the field, if necessary. Common entity examples would be: 'ditch', c/L road','road edge', 'hydro pole', or 'transformer'. A menu of up to twenty user-defined entities can be used.

During field operations an attribute of an entity (e.g. colour, serial number, type) can also be entered by the operator at the time of data collection. The attribute and entity are stored in a data file together with a three-dimensional position and precise time. Position and time data can also be collected in the data file either at a preprogrammed time interval between 1 and 99 seconds, or at a preprogrammed distance interval greater than 100 metres. Thus for a mobile user, a trace of position and time can be stored in the file. As the operator is moving around on the 'real-world map' collecting data at chosen points, digitizing at a one-to-one scale is taking place.

When two or more units are used in the differential mode, the base receiver is set up connected to an IBM-compatible computer that acts as a stationary data-logger. Data is recorded at an interval (say every 10 seconds) that will ensure variations in satellite derived positions are recorded. Field data and base data sets are then post-processed so that corrections may be made to the field set.

ACROSTAR PROCESSING SOFTWARE

Acrostar provides a post-processing software package to allow the user to transfer data files from Geologger II equipment and to process them into a convenient format. The package is called Acromark, and it can run on any Personal Computer or compatible machine. The computer must have at least 640KB of main memory, a hard disk and a serial port. A printer is required for obtaining hard copy of satellite visibility plots. The functions provided by Acromark are data file transfer, satellite visibility and geometry prediction, differential GPS correction, map datum transformation and GIS format conversion.

Transfer of data files from the Geologger II to the processing computer is performed using the serial port. The time taken to complete the transfer varies from less than five minutes to half an hour or more for large base station files. When the transfer of a data file from the Geologger II is complete, the user is prompted by Acromark to determine whether the satellite almanac contained in the file should be saved on the hard disk. The GPS receiver collects the almanac and stores it in the data file. The almanac contains the orbital parameters and status information for every satellite in the GPS constellation.

It is necessary to store the almanac in order to do satellite visibility and geometry calculations. It should be updated periodically in order to reflect the removal from service of early GPS satellites, the launch of new ones and other constellation changes. Finally, the transfer function scans the data file and displays the date, start and end times of the data file, and the maximum and minimum latitudes, longitudes and elevations in the file.

Satellite visibility and geometry prediction allows the user to perform mission planning in advance of field operations. This is a vital feature, particularly during the build-up of the satellite constellation, since it is not possible to obtain satisfactory geometry at all times of day.

The user can obtain graphs of the number of satellites visible, the Position Dilution of Precision (PDOP), and the Horizontal Dilution of Precision (HDOP) for all times during the day of interest, and the rise and set times and elevation and azimuth angles for each satellite in the constellation. The user must enter the approximate coordinates and date for the proposed field operation in order to obtain these graphs. The graphs may be printed on a dot-matrix printer or laser printer if desired.

PDOP and HDOP are measures of the quality of the satellite geometry at any given time,

and they directly affect the position accuracy obtainable. PDOP is a measure of three-dimensional geometry, while HDOP is a measure of horizontal (two-dimensional) geometry only. For users who are not interested in elevation data, HDOP is the more useful measure, and these users may obtain useful results even at times when the geometry in the vertical direction is poor.

When performing differential correction, the user must first transfer the Geologger II base station data file and mobile data file into the processing computer. On the differential corrections menu, the user specifies the names of these two files, the precise coordinates for the base station antenna, and the name of an output file.

In order to perform differential correction, the position data in the base station and mobile files must have been collected at the same time. Acromark provides two methods of differential correction, known as solution space and measurement space correction.

The solution space method takes filtered position coordinates from the base station file and subtracts them from the precise coordinates for the base station antenna to yield a correction in three dimensions. This correction is then added to the filtered position coordinates from the mobile file which have the same time tag as the base station file. This process is repeated for every position point in the mobile data file which has a corresponding point in the base station file. The limitation of this method is that both receivers must track the same satellites in order to achieve a reliable result. This condition may not be met at all times, particularly if the receivers are widely separated, or if either receiver operates in an environment where signals are obscured from its antenna by buildings, trees, terrain or other obstructions.

The measurement space correction method overcomes the problem of dissimilar satellite constellations at the base station and mobile receivers by computing corrections to the pseudoranges (i.e. satellite to user distance less receiver clock bias) for every satellite being tracked at the base station, and applying these to the pseudoranges measured for the same satellites at the mobile. Satellites which are not common to both receivers are thereby excluded from the solution.

The measurement space method requires that there are at least four satellites common to both receivers (three for a two - dimensional fix). Filtering of the corrected pseudoranges to achieve position coordinates is performed by the correction software. The measurement space software used by Acromark is the C3NAV package developed by Gerard Lachapelle and Elizabeth Cannon of the University of Calgary.

The map datum transformation function allows the user to transform position coordinates from the WGS-84 (World Geodetic System 1984) datum used by GPS to other datums. NAD-27 (North American Datum 1927) is the most widely used datum for existing maps of

North America. It is now rapidly being replaced by NAD - 83. The transformation from WGS-84 to NAD-27 is complicated by the fact that the transformation parameters vary depending on location. Acromark provides average transformation parameters for the continental United States, and for Canada. Alternatively, users may enter their own set of parameters if they are known with precision. Contour charts may be obtained which indicate the parameters to be used for any location in North America. Acromark also provides a transformation from WGS-84 to UTM (Universal Transverse Mercator) cartesian (x-y) coordinates.

The GIS function of Acromark allows the user to select the required data and to format it for use by a Geographic Information System. Depending on application, the user may select every position datum in a file, or only those associated with an entity or remark entered in the field. Time and position are processed into a tabular format, together with GPS status (e.g. 2-D or 3-D position fix), Differential correction status (e.g. valid differentially-corrected, or non-differential), HDOP and VDOP (vertical dilution of precision). Acromark will then generate a text format output file containing this information. This data may be easily incorporated into most spreadsheet or database systems.

INITIAL CONVERSION SOFTWARE

Before Acrostar developed the software package just described, a prototype system was developed to prove the feasibility of using GPS to put data into a GIS. The target GIS chosen was TerraSoft Version 9 from Digital Resource Systems of Nanaimo, B.C. This is a modular PC based system available to 286 (AT) machines and up. The following sections trace the development and testing that was carried out.

As previously described the Geologger II generates an output file that can be downloaded from the logging unit to an IBM compatible machine. Initially, conversion software was written that looked at this output file and extracted the latitudes, longitudes, and elevations. This information uses a geocentric WGS 84 spheroid and generally must be converted to the non-geocentric Clarke 1866 spheroid on which the North American Datum 1927 (NAD27) is based in order to be compatible with most existing data. Universal Transverse Mercator (UTM) coordinates are then generated using the converted geographics and stored in a UTM file.

The software then takes the UTM file which also contains the entity information and attributes that were entered during data collection and translates this information to the TerraSoft Data Exchange Format (TDEF), which is an ASCII file containing all information pertaining to mapped objects . The operator must input desired scale, map name, map limits, and the layers on which various entity information is to be placed.

The TDEF file is usually a large file which can then be converted to a smaller binary

format TerraSoft drawing file using a TerraSoft utility which is supplied to all users. The TDEF can be deleted after translation. Data collected in the field is shown as lines or points on appropriate levels along with any notes. Any editing can be now carried out using the normal procedures available in TerraSoft. New data can now be merged with existing information to provide an updated map file.

The language used to prepare the Geologger II data to TerraSoft conversion program was BASIC, which has been greatly enhanced by MicroSoft with QuickBASIC, and is now a powerful tool enabling programs to be developed quickly and efficiently. QuickBASIC provides a modular programming system which allows the use of separate procedures so that program changes can be made to keep pace with changing equipment and formats.

By illustrating the ease with which a language such as BASIC can be used to create a GIS interface, the authors hope to show that most computer users can approach the GPS-GIS interface problem even if they are not expert programmers. Considering the growing use of 'Windows' programs, it should be mentioned that a program in QuickBASIC can be quickly transferred to VisualBASIC, which is a development tool aimed at providing software for Windows users.

SYSTEM TESTING

The GPS-GIS interface was initially tested on a small data set collected near Ottawa. Once the necessary filter software had been developed and tested, a more comprehensive test was planned.

The purpose of the new test was threefold:

1. To create various data sets that could be studied after entry into TerraSoft. Of interest were the mechanics of the data filter that transferred the GPS coordinate data into TerraSoft, and the quality of the GPS layer when compared to some existing standard for the area such as a digital map. Issues regarding the interpretation of GPS data once it is in a GIS system were also of interest.

2. To evaluate several different GPS methodologies including differential corrections and kinematic GPS. Of particular interest was a comparison of GPS data which had been differentially corrected with the same data computed using kinematic processing software. The test courses were chosen without regard to possible sources of cycle slips at the roving receiver (such as driving under a bridge), resulting in less than ideal conditions for a kinematic survey.

3. To develop efficient data collection techniques. The logistics used to collect the data are of importance because the time needed to complete the data collection must be minimized and also because a poorly designed mission may result in additional work

when the GPS data is filtered into the GIS.

Two test courses were designed: one to create a map update through the continuous collection of coordinates; and one to map a new subdivision and record entity information.

The Geologger II receivers were modified by Acrostar so that they would record the necessary information to process the data using differential corrections as well as that information needed by the kinematic software SEMIKIN.

The Geologger II data files are organized so that ASCII entity and coordinate information is integrated with binary time-tagged phase information. Thus one filter can be used to extract raw coordinate information along with entity data. It only remains to process the data with either a differential processing program or kinematic processing software. Once this processing is complete, the time-tagged entity information must be associated with the time-tagged processed results. In either case all that is required is a simple program that can place the results into a standard format which can then be converted to the format required by a GIS.

It becomes clear that the GPS-GIS conversion function can be standardized as long as simple conversion filters are written to accept data from several GPS processing programs. In this way, the GPS processing technique used is only important as it relates to the accuracy required for the coordinates which are ultimately placed in the GIS.

A base station was established on a geodetic control station called CORKY. This station is part of the Geodetic Survey of Canada GPS Basenet in Ottawa. An offset was established about 25 metres from CORKY to provide an initialization point for the roving receiver so that the data could be processed using kinematic techniques, as well as with differential software.

The first test course covered the Queensway from Kanata through to the east end of Ottawa. An antenna was placed on the roof of a car and GPS data was sampled at a rate of once per second. The route was covered twice: eastbound from Kanata in the slow lane, returning westbound to Kanata in the slow lane; and a similar route in the fast lane. Care was taken not to change lanes during each pass. The vehicle stopped at several exit ramps to measure data at temporary check points.

When the data was processed and filtered into TerraSoft, not only the different directions easily distinguishable, but also the individual traffic lanes. The GPS data layers were overlaid onto the street network line data of the area from the Area Master File (available from Statistics Canada) and the agreement obtained was excellent. In areas where there was a disagreement, an explanation was usually apparent. For example, where the vehicle left the Queensway to establish a check point, the existing ramp as plotted by the GPS

system was not the same as the Area Master File map. In fact, this exit had been rebuilt recently and GPS was mapping that update.

It is obvious that the choice of a sample rate (epoch) is important. For example, if the vehicle is travelling at about 30 metres per second (about 110 km/h), then it is possible to lose a sample when the vehicle travels under a bridge. It is important when interpreting the results to keep in mind the parameters of the GPS data collection so that errors in the interpretation of the data do not occur. In this way it seems that GPS-GIS data interpretation is somewhat similar to photo interpretation.

The second test course was in the recently developed area called Kanata Lakes, several kilometres to the west of station CORKY. The subdivision was first mapped by a car with a GPS antenna placed on the roof. The GPS receiver was initialized to collect data at a one second epoch. The streets were covered in one run with no effort to recover inventory information. A second pass was then made to collect discrete entity information for inventory purposes.

The Geologger II menu system was set to record a number of entities such as manholes, fire hydrants, telephone boxes, and super mail boxes. The entity names were first initialized into the system by the operator so that they became part of the menu system in the receiver software. The operator with a range-pole mounted antenna went to the data points by vehicle, placed the range-pole on the required spots and selected the correct entity names from the menu. In this way the receiver coordinates recorded during the time at an entity were associated with the entity name selected by the operator.

The results were filtered into TerraSoft in two layers: the horizontal road profile; and the point locations for various entities. This information comprised the whole map of the subdivision because no other maps of the area exist.

The second test was particularly interesting in that it helped to answer questions about the best and most efficient way to collect both horizontal profile and point information. After several experiments it was clear that the best way to collect the data was to separate the data collection processes into two phases, rather than to try and collect the profile and point information at the same time.

FUTURE DEVELOPMENTS.

The Geologger II has an hardware upgrade available which allows the receiver to monitor the phase of the incoming satellite signals. As mentioned earlier, this means that the accuracy of the data is equal to or better than that obtained using normal survey methods. Work needs to be carried out to further refine the current software applying lessons learned from the past testing.

Conversion software must also be written translating Geologger II output files to other GIS's not yet addressed by Acrostar's Acromark software. A Version 10 for TerraSoft has recently been introduced and should be taken into account when planning future software.

SUMMARY

What makes GPS so exciting to the GIS user is the large variety of problems related to inventory and profiling that can be tackled. A GPS system with entity recording capability (attaching a name to a time-tagged coordinate) allows the user to quickly and efficiently collect coordinate information om a way that has not been possible in the past.

If the GIS manager wants to coordinate information of a certain accuracy and type, it is only necessary to assemble the correct GPS equipment and software and use the best applicable GPS methodology. The information resulting from the GPS data collecting will lend itself easily to the necessary data transformation and reformatting in order to make it useful to a particular GIS. Once this interface is complete, the trip from "1:1 digitizing" to the updated map is simple and smooth.

SURFACE INTERPOLATION AS A VORONOI SPATIAL ADJACENCY PROBLEM

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Spatial information may be viewed in two ways: as coordinates measured with a ruler along imaginary axes; or as the adjacency relationships between objects. The former was the most common historically, but the latter appears more relevant to the handling of spatially distributed objects in a computer.

The interpolation problem, as implemented using weighted-average techniques, depends on the selection of appropriate neighbours to the sample location being estimated. Traditionally this was done using "metric" methods, with sometimes unsatisfactory results. An alternative "adjacency relationship" approach can be used, based on the construction of the Voronoi regions about each point, that removes many of the inconsistencies of the earlier methods and provides an integrated weighting method for each adjacent point. Interpolants can then provide appropriate levels of continuity.

The technique may be extended to data objects besides points, in particular to line segments, permitting consistent integration of elevation information at break-lines, contour segments, etc. as well as at point locations. The concepts discussed are here applied to two spatial dimensions plus "elevation", but the Voronoi method may readily be applied to higher dimensions.

L'INTERPOLATION DE SURFACE COMME PROBLÈME DE CONTIGUÏTÉ SPATIALE DE VORONOI

RÉSUMÉ

L'information spatiale peut être vue de deux façons : des coordonnées mesurées au moyen d'une règle sur des axes imaginaires, ou des relations de contiguïté entre des objets. La première était la plus répandue autrefois, mais la seconde semble plus utile pour le traitement à l'ordinateur d'objets distribués dans un espace.

Le problème de l'interpolation, utilisée au moyen de techniques à moyennes pondérées, réside dans le choix approprié des éléments voisins du poste d'échantillonnage faisant l'objet de l'estimation. Autrefois, on se servait pour se faire de méthodes "métriques", ce qui donnait parfois des résultats médiocres. On peut prendre une autre approche, celle de la "relation de contiguïté", basée sur la délimitation de régions de Voronoi pour chaque point, ce qui élimine plusieurs des lacunes des méthodes utilisées antérieurement et permet de faire une pondération intégrée pour chaque point adjacent. Avec les valeurs interpolées, on peut alors obtenir le degré de continuité approprié.

Cette technique peut s'appliquer aux objets informatifs à côté des points, en particulier aux segments de lignes, ce qui donne une intégration homogène des renseignements sur l'élévation aux lignes de rupture, aux segments de courbes de niveau, etc, ainsi qu'aux points. Les notions examinées s'appliquent ici à deux dimensions spatiales (indépendantes) ainsi qu'à "l'élévation", mais la méthode de Voronoi peut facilement s'utiliser pour des dimensions plus élevées.

INTRODUCTION

In the world of GIS, "interpolation" is taken to mean a rather limited operation applicable to such applications as terrain modelling, contouring, or TIN (Triangulated Irregular Network) construction. This paper attempts to show that interpolation is a more general operation than this. In order to do so we must first introduce the idea of "Proximal Query Space", and its breadth of application, and then describe some techniques that are sufficiently general to make the approach operational, for various map types and numbers of dimensions.

PROXIMAL QUERY SPACE

If one points at some location on a map (any kind of map) it is reasonable to expect some meaningful response. The human observer would not be satisfied with "nothing" as an answer, except in extraordinary circumstances. Historically, of course, if large areas of the map were "terra incognita" then a variety of fanciful icons were employed, such as whales, ships or imaginary beasts. Alternatively, if a textual description was deemed necessary, "Here Be Dragons!" was an appropriate response. In the GIS situation it is assumed that large portions of the map are not completely unknown, and hence the "HBD" response is invalid.

Nevertheless, for many GIS's and map types, HBD would be the response to most available query points. A road or stream network, for example, has no meaningful response for queries that fall between line segments, although for a polygon map the query would be meaningful. A set of survey points would also usually return a value of HBD in response to a query. This is clearly inadequate, if only because it is at variance with human experience, which persists in believing that space is not empty, and will frequently attempt to reply with the name of the nearest map object.

"Proximal Query Space" is therefore a "natural" mode of interaction between the user and the map data and, as will be shown, a reasonable method of posing location queries within the spatial algorithms themselves. How does this relate to the "Interpolation Problem"?

INTERPOLATION

In traditional interpolation a variety of global and local methods may be used to estimate the value of the "elevation" (or some other dependent variable) at the desired query location. We will ignore for the purposes of this discussion the global techniques, such as trend surface or polynomial trend analysis, that use all the data to estimate any one query. Local methods of interpolation must therefore select a set of nearby data points that will be used to estimate the elevation value at the query point. At this stage either a local polynomial patch or a

weighted average are used to make the estimate - more frequently a weighted average, due to the problems of higher-order continuity between adjacent polynomial patches (see Gold 1989).

The simplest form of interpolation - one that is still used in remote sensing - is to query the map and return the "elevation" value of the nearest data point. (This is used for some simple forms of image rectification or resampling.) This is equivalent to the previously defined proximal query space. Hence this interpolation is a form of query, returning the value (radiosity) of the nearest pixel. This also goes by the name of "proximal mapping" in the computer mapping literature. A sufficiently dense grid of queries of an arbitrarily distributed set of data points would produce a map with polygons coloured according to the nearest data point. These polygonal regions are called Thiessen polygons, Dirichlet tessellations or, more commonly, the Voronoi diagram of the point data set.The simple proximal query is here denoted a "Type I" query. Figure 1 shows a Voronoi diagram of a simple point set.

CONTINUOUS SURFACE INTERPOLATION

Perhaps the most common form of interpolation assumes that the data point elevation values are samples from a continuous smooth surface. It attempts to generate query replies that, if asked for a dense grid over the map, would generate a continuous, smooth surface, based, for each query point, on some form of weighted average of the values of a reasonable set of neighbouring data points. Rephrased as a query, when some particular location is designated, the resulting reply is a set of nearby data points and elevation values, together with the appropriate weighting values for each. This is here referred to as a Type II query. Thus a small perturbation of the query point might result in the same set of neighbours but with slightly different weights, while a larger perturbation would change the set of neighbouring points. In principle, a query point that coincided with a data point would return a neighbour set consisting only of the one data point, with a weight of 100%. Most interpolation schemes, however, fail to precisely honour the data point values in this fashion, or else the surface itself is neither smooth nor continuous. Surprisingly, this is true for most of the common local techniques, as well as for global methods. Details are given in Gold (1989). This will be summarized below, firstly for polynomial methods, and then for weighted averages.

Polynomial Patches

It is not surprising that a global polynomial, although smooth and continuous, does not pass through every data point on a map unless it has a great many terms - and hence is very unreliable in between data points. Local polynomial patches can be made to fit to the data points in a local region, but it is rare that they can be made with greater than first order smoothness between patches. It would seem that having a continuous slope between

patches would be sufficient, but experience shows that rapid changes in curvature, even when slope is continuous, is easily detected by the readers of a contour map - leading to reading fatigue, irritation and misleading interpretations. In other words, the algorithm generates artifacts: features that are not necessary to fit the surface to the data.

Often the patch used is a triangle connecting three data points, and a cubic polynomial is employed. This gives the level of continuity or smoothness described above. Where a linear polynomial is used the result is a planar triangle between the three elevation values - the common TIN. In both of these cases the selection of the triangulation algorithm affects the resulting surface significantly, although in the last ten years or so the Delaunay triangulation has been widely adopted. This, the dual of the Voronoi diagram of the data point set, is the only known definition of a triangulation that is guaranteed to remain unchanged (except for degenerate conditions) no matter what the order of data point entry, and is also guaranteed only to change locally when a data point is inserted, deleted or perturbed.

Weighted Averages

Weighted average methods are also subject to the problems of preserving continuity and smoothness, and honouring the data points. The most common traditional techniques use a distance based weighting, decaying either as $1/d^2$ or as a gaussian "bell curve". In the first case the weighting is infinity when d=0 (i.e. the query point is on the data point), and hence the weightings of all other neighbouring points become insignificant. In the second case the weighting becomes 1 when d=0, and the contributions of neighbouring points with non-zero weightings prevent the surface from honouring the data point.

A far more serious problem, however, is that the weighting functions decay towards zero at great distances from the data point, but are by no means insignificant for most arrangements of data. Not only may this prevent data points from being honoured, but it causes discontinuities - cliffs - in the interpolated surface whenever a data point is added to or deleted from the set of neighbours of a moving query point. Ideally a data point weight should reach zero at the time that it is rejected from or accepted into the set of neighbours, but this is impossible for weighting functions that only reach zero asymptotically. The weighting function and the neighbour selection criteria must be much more strongly coupled: most computer programs use a variety of arbitrary neighbour selection criteria (search radius, quadrant search, etc.) that often make the discontinuity problem worse (e.g. when a data point is rejected not because of distance, but because it falls outside a particular octant). See Gold (1984,1989) for further details. A solution promoted for several years by this writer directly couples a neighbour selection criterion with a finite-range weighting function. It is

based on a more detailed definition of "neighbour" and "adjacency".

Voronoi Neighbours

The Delaunay triangulation is one way of defining the set of data points that are neighbours to any particular point: if they are connected by a triangle edge they are adjacent. This is equivalent to saying that if the Voronoi zones of two data points have a common boundary, the two points are adjacent. Figure 1 shows the Voronoi regions mentioned previously and the related Delaunay triangles. Thus, in order to determine the (Voronoi) adjacency of any pair of data points, first construct the Delaunay triangulation or Voronoi diagram (the two operations are equivalent). It follows that in order to determine the neighbouring data points to some query point - first insert the query point into the Voronoi/Delaunay structure, and then examine its neighbours. (It should be noted that in order to prepare, say, a contour map many query points need to be inserted - and deleted individually, immediately after use, in order not to interfere with subsequent nearby queries. This demands a dynamic Voronoi/Delaunay data structure that permits incremental point insertion and deletion. See Gold (1992, these proceedings).)

Voronoi Weighting

If the Voronoi definition of adjacency of data points is accepted then a Type II proximal query does not return the closest object, as did the Type I, but instead returns the set of Voronoi neighbours. However, some neighbours are closer than others - but none will be behind other neighbours, as may be the case with simple distance based methods. How are we to select the more "important" points? This is equivalent to specifying the interpolation weighting function described previously.

The insertion of the query point Q into the Voronoi diagram has clearly only modified the immediately surrounding portion of the data structure - those Voronoi regions that are now adjacent to the newly inserted query point. They <u>are</u> adjacent precisely because a portion of their previous extent has been lost to provide the new point with <u>its</u> own region (see Figure 2). If Q is mid-way between several data points, the "stolen areas" of each will be approximately the same. If Q is then moved until it coincides with a data point P, all its stolen area will be taken from the Voronoi zone of P. If Q is moved half the map away from P, then it will cease to steal <u>any</u> of its own area from P, but will take it all from closer data points instead. The location at which Q ceases to steal any area from P is precisely that location at which the Voronoi regions of Q and P cease to have a common boundary - that is, they cease to be Voronoi neighbours. We thus have a "stolen area" weighting scheme that corresponds to our requirements for a finite range. As previously discussed, this is required for the surface to honour the data points, and also to prevent surface discontinuities as data points are added

to and subtracted from the neighbouring set. In addition, the weighting reaches 100% when the query point coincides with a data point, ensuring that the surface honours the data points. The remaining problem is the smoothness of the resulting surface.

This weighting function approach guarantees that, as the query point approaches a data point, the weight approaches 100%. It does not guarantee that the same data point, approached from the other side, will be approached with the same slope. Similarly there will be a break in slope precisely where the weighting function becomes zero. The result is a surface somewhat like a series of overlapping volcanic cones, one at each data point. Sibson (1982) used these "linear" weighting functions in a final "spherical polynomial function". Gold (1989) applied a simple Hermitian polynomial to "smooth" each weight before it was applied, guaranteeing zero slope to the modified weighting function whenever the original weight reached zero or unity. This preserved the advantage of using weighted averages throughout. He also applied these weights to the function at each data point, thus permitting the preservation of original or derived slopes at each data point. Watson and Philip (1987) blended the linear weights and the slope data to achieve the same objectives. In all of these cases, applied to achieve slope continuity, the more fundamental properties of surface continuity and data point honouring are preserved, due to the finite range of the weighting functions employed. One particular advantage of the area-stealing method is that it is adaptive to the data distribution, as with a TIN, but for awkward data distributions, such as flight line data, a far greater potential number of data points are involved. Figure 3 shows the result of performing full area-stealing interpolation on a set of seismic data using Gold's method. This compared well with available commercial systems.

OTHER FORMS OF INTERPOLATION

To summarize, "Type I" interpolation returns the name of the nearest map object, and its value is used. "Type II" interpolation returns the set of neighbouring map objects and their associated weights. These weights may be modified (e.g. to produce satisfactory slope continuity) and are then applied to the functions or values of the associated map objects. In our examples so far these "map objects" have been data points.

One of our early examples of Proximal Query Space was a stream network. A Type I query or interpolation returns the name of the nearest map object - in this case a stream segment. In the same fashion that it is possible to define the Voronoi zones around a set of points, it is also possible to define the Voronoi zones (i.e. the proximal region) around line segments. This is described in Gold (1990). He uses a dynamic incremental technique, where points are created by splitting a nearby point and moving the newly created point to the desired location. Similarly, deleting a point consists of moving it to a nearby point and then merging the two. Line segments are generated as

the locus of the moving point. In all these cases the movement of one point at a time, while maintaining the Voronoi spatial relationships, is central. The result of this operation on our digitized stream network is a set of Voronoi zones about each point or line segment forming the network. Using this we may derive out Type I query.

As described in the same paper, it is also possible to apply a Type II query to the same data. In this case the inserted query point would steal areas from the adjacent Voronoi zones of points and line segments, and return the set of neighbouring map objects and weights. If elevation values were assigned to the digitized network (and, in order to make this useful, to a ridge network or other survey spot heights) then weighted average interpolation may be applied to the results. Thus interpolation consists of applying either a Type I or a Type II query at the desired location, and then performing the desired weighted averaging as required. This process is particularly useful in the case of digitized contour input.

A good example of the difference between Type I and II queries for categorical data concerns the rock types on a geological map. Frequently the original data consists of the identification of a rock type at each of a set of widely separated outcrops. A Type I interpolation consists of the proximal zones around each outcrop, making an estimate of the map regions covered by each rock type. A Type II interpolation, using an area-stealing weighted average, will assign a particular rock type to a location if it has the largest fraction of the total weights (or some other criterion). Either approach may be used, depending on the desired effect.

Polygon maps

If the points and line segments are used to form a polygonal map and the associated Voronoi diagram, as in Figure 4, it is then necessary to assign the polygon name to each point and half line - since each side of a line segment is given the "colour" of the associated polygon. This is equivalent to the elevation value used previously as the attribute associated with each map object. A Type I query would then return the name of the nearest object - which will be one of the edges or vertices forming the polygon. The associated value is therefore the desired polygon name. A Type II query will achieve the same end - at greater effort. The areas stolen by the query point will all be taken from edges and vertices forming the same polygon, and so no matter what the weighting, the resulting interpolated value will be the polygon name again! This shows that the point-in-polygon problem is indeed a form of interpolation - but interpolation of a surface with cliffs in it at all polygon boundaries. This idea is directly extendable to a continuous surface with cliffs (as in a geological map with faults) - each side of the line may have a different associated attribute or function, and within any individual region not separated by line segments regular smooth interpolation would apply.

Another form of polygon map problem occurs when a particular attribute value is associated with each polygon (e.g. census data). It is therefore assumed that the whole polygon has the same value. This is equivalent to the previous case, where a single attribute value is assigned to all the points or edges forming the polygon. Any Type I or II interpolation will return the polygon attribute value. If, however, the attribute value for a particular polygon is unavailable, how may it be estimated from its neighbours?

One solution to this problem (Tobler and Kennedy, 1986) weights the neighbouring polygons by their respective boundary lengths - but one highly convoluted boundary would invalidate this method. An alternative, using the Voronoi approach, is to imagine the polygon itself deleted, leaving a hole: the neighbouring polygons would then have Voronoi regions within this unoccupied hole (see Figure 5). (These regions are readily determined using the usual Voronoi algorithm.) Replacing the polygon would therefore "steal" these Voronoi regions, and the weighted average could proceed as usual. Thus the same technique is appropriate as for the other interpolation problems, but here the "map objects" are the remaining polygons themselves.

CONCLUSIONS

"Interpolation" is a more general procedure than is generally acknowledged, and is closely associated with the idea of a "spatial query" at some desired location. If the Voronoi concept is adopted, then a "Proximal Query Space" may be established, defining proximal zones about each map object. These map objects may be of any form, but only those constructed of points and line segments have been implemented.

Within this query space two query types, I and II, have been defined - the first returns the nearest object only, the second returns a set of neighbouring objects and their weights, based on "area-stealing". (These can be referred to as "non-invasive" and "invasive" respectively.) Either, but Type II in particular, may be considered the basis for interpolation.

Various applications have been suggested for Voronoi based interpolation, indicating the wide range of possibilities, the generality of the method and the ability to mix data types and queries that were previously handled by widely disparate techniques. For smooth interpolation of continuous data the methods described appear to have significant advantages.

The methods described, besides being applicable in principle to many types of map object, may be applied in various metrics and dimensions. In particular, three dimensional point interpolation, based on the same principles as the two dimensional case (but stealing volumes instead of areas) appears to be of considerable interest.

ACKNOWLEDGEMENTS

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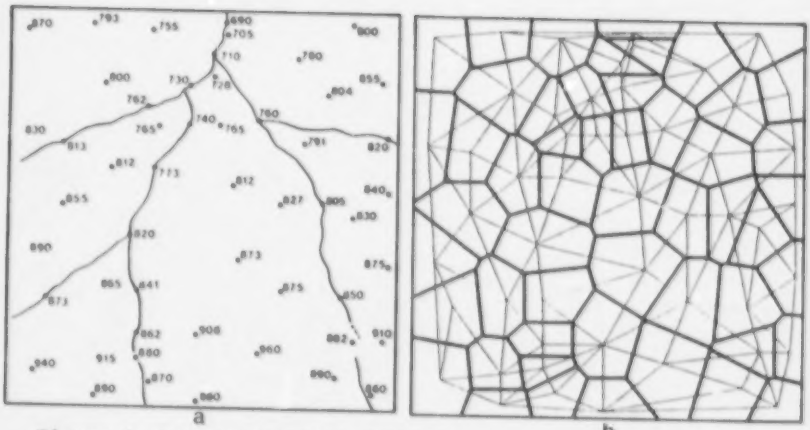

Figure 1. a) Simple point data set, and b) resulting Voronoi diagram and Delaunay triangles

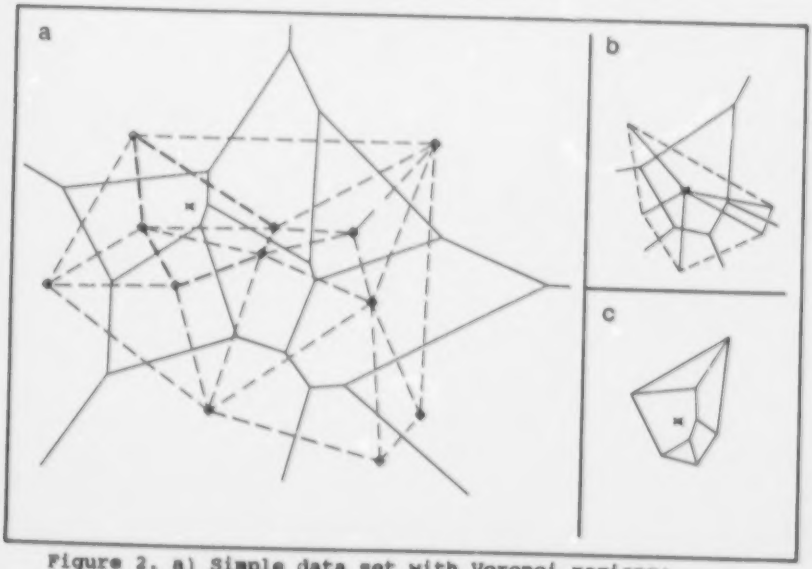

Figure 2. a) Simple data set with Voronoi regions;
b) Voronoi region after insertion of point X;
c) Neighbouring areas stolen by point X.

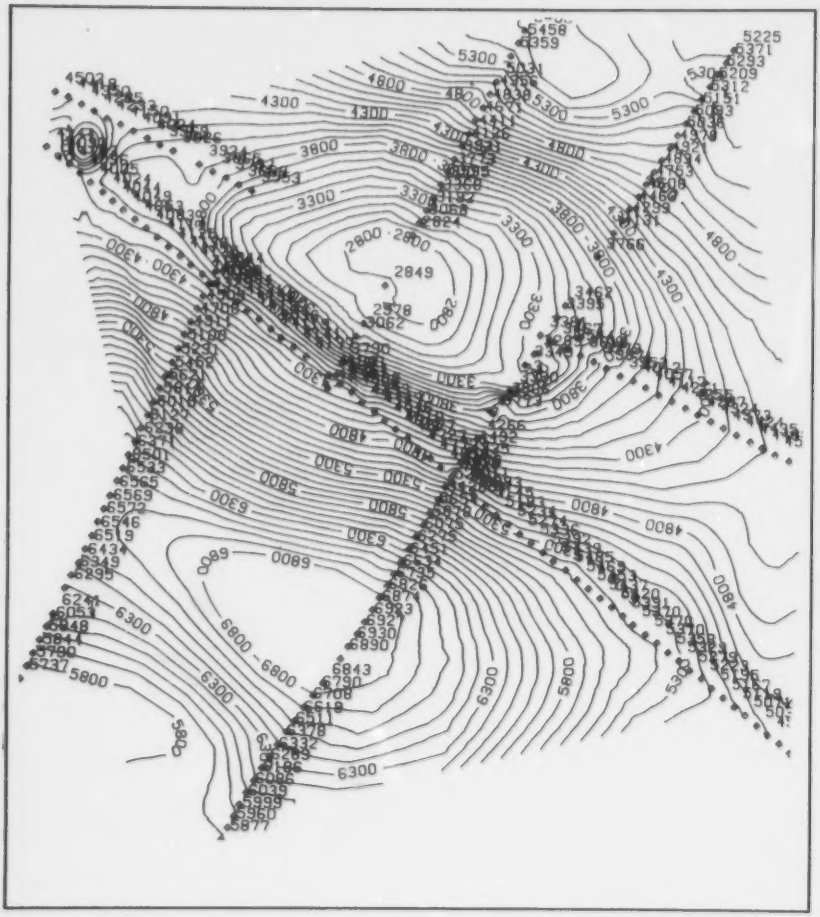

Figure 3. Seismic data: Area stealing interpolation

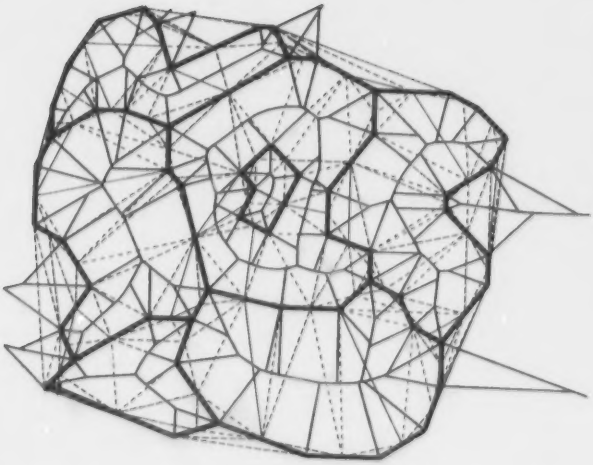

Figure 4. Polygon map (heavy lines) with associated Voronoi regions (medium) and Delaunay triangles (dashed).

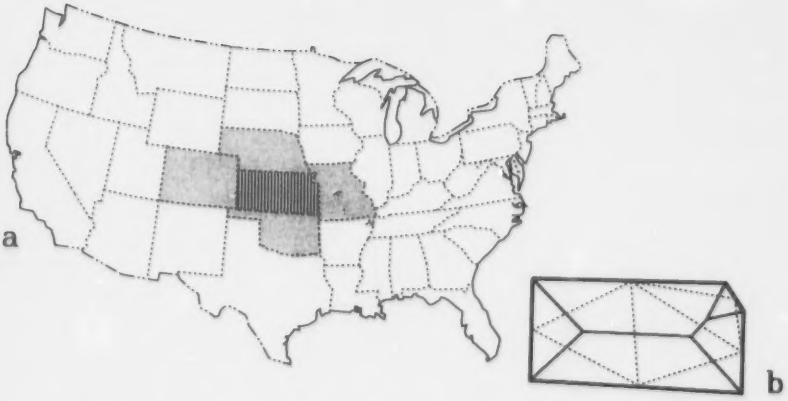

Figure 5. a) Neighbouring states to Kansas
b) Voronoi areas of neighbouring states

THE INTEGRATION OF REMOTELY SENSED DATA ANALYSIS INTO GIS: TIME AND UNCERTAINTY MANAGEMENT NEEDS

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The integration of remote sensing image analysis with GIS technology requires, among other issues, the development of automated and efficient time-management capabilities in GIS software. Remotely sensed images are obtained at intervals ranging from a few minutes to many years, and hence the time management of these data is often more exacting than that of typical cartographic data. Furthermore, effective means of handling uncertainty must be introduced if the results of temporal analyses are to be meaningful. These issues are discussed in some detail, along with research being carried out to put such a capability together.

L'integration de l'analyse d'images de teledetection et les systemes d'information geographiques (GIS) implique le developpement de nouvelles competences pour une gestion efficace et automatique du temps a l'interieur des GIS. Les images de teledetection sont obtenues a des intervalles passant de quelques minutes a des annees. C'est alors que la gestion temporelle de ces donnees est plus problematique que pour les donnees cartographiques traditionnellement traitees par les GIS. De plus, des moyens de comprendre et d'exploiter l'incertitude (a la fois spatial et temporel) doivent etre introduits si les resultats des analyses vont avoir un sens. Dans cet article, ces questions sont abordees en detail, ainsi que la recherche menant au developpement de ce technologie.

1. INTRODUCTION

Several researchers have stressed the importance of integrating remote sensing image analysis into geographic information systems (Cicone, 1977; Green et al., 1988; Ehlers et al, 1989; Sauchyn and Xongchao, 1991). It is now widely recognised within the remote sensing community that this is not only important, it is necessary if the data is to be exploited fully. In a survey of integration efforts (Ehlers et al, 1989), it was noted that most efforts to data have involved developing data exchange formats between GIS software and image analysis systems (IAS). A parallel was made between GIS/IAS integration and DBMS/digital cartography, the latter integration leading directly to GIS technology. A three stage process was outlined, beginning with data exchange formats, passing through tandem software running under a common user interface and ending with a fully integrated system. It was also noted that integrating IAS into GIS software is a necessary evolutive step even within the GIS community, because such integration is linked inexorably with handling time and exploiting knowledge-based technologies.

Over the last two or three years, the management of time within GIS has become one of the "hot" research topics, and probably will remain so for the next decade. Research is occuring at many different levels in order to handle the different aspects of the problem. Indeed, the problem is very challenging. Until recently, no conceptual framework existed for handling time as anything else but an attribute of raster grid cells. Furthermore, very few existing vector GIS contain the ability to handle rapid modifications to the topology in a truly dynamic fashion. No clear idea of how to introduce temporal elements in database management exists either.

Over the past year, new work has begun to emerge which begins to provide the skeleton of a conceptual framework for time management inside GIS (e.g. Al-Taha and Barrera, 1990; Gagnon et al, 1992). Furthermore, new spatial data structures which are demonstrably dynamic are emerging (Herring, 1987; Gold, 1991).

The study of time management of GIS indicates that for urban and municipal settings, immediate needs require temporal units of resolution of about a month to be practical. Smaller resolution than this may be useful for some tasks, but for most needs this is percieved to be adequate. Also, new spatial elements are expected to be added to the database on a regular basis.

This suggests that the management of temporal elements could be handled. by identifying a minimal unit of resolution of one month and dividing time up into monthly units. This would be like a time-raster. For many contexts such an approach is probably workable.

It is my contention, however, that for contexts other than urban and municipal settings and also for the management of remotely sensed data, the raster approach to time management will quickly become too limiting. Let's take a closer look at the temporal nature of remotely sensed imagery.

2. THE TEMPORAL NATURE OF DATA USED IN REMOTE SENSING IMAGE ANALYSIS

Remotely sensed image data is characterised, typically, by at least two and sometime more time scales. In the case of satellite data, images of the same scene may be acquired at two to three day intervals. In practice, atmospheric conditions over most of the earth limit data acquisition over the same site to some time period between every few months and more than

a year. In the case of airborne imagery, several images of the same site are usually acquired for a given flight because the major cost of the image comes from air time. Atmospheric effects may limit the actual flight to windows several weeks apart in the summer and less frequently in other parts of the year.

For intensive campaigns on the same site, or operational programs requiring ongoing image acquisition over long periods, acquisition dates from a variety of airborne and satellite sensors may be involved. The timing of the image acquisition may also be coordinated with ground measurements and with the production of new maps of the area. Figure 1 shows an example of what this might look like. Hence both a very fine-scale timing distribution is present (high temporal frequency) as well as a coarse-scale non-periodic or semi-periodic timing distribution.

Depending on the applications for which the imagery was acquired, the smallest meaningful time intervals may range from a few minutes (even a few seconds in some extreme cases) to a few days. The temporal profile of data acquisition will also, however, be characterised by long periods in which nothing occurs. This is especially true of operational programmes. Hence managing this data requires temporal precision down at least to the minute over durations of several years, but within which large gaps occur.

Such a situation is suggestive of vector-like operations. By allowing each object to use the temporal precision appropriate to that object as a "coordinate", we treat events as coordinates and not as raster-like units.

Furthermore, ground truth data acquired during the image acquisition may also need fine temporal resolution. A case in point is any data used to help perform atmospheric corrections on the image data. In this case, resolutions near a minute may be essential to untangling certain effects. A number of effects are certainly important on an hourly basis, such as the changing reflectance properties of objects as the sun changes its illumination angle.

In terms of using maps and other spatial data for validating and evaluating remotely sensed imagery, for operational campaigns, ground truth maps are expected to change fairly frequently for most applications over a period of a few years. Hence our ability to incorporate these changes into the GIS will significantly improve our analysis capability for these images.

In summary, the management of remotely sensed imagery, both for intensive field campaigns and operational programs, requires, on the one hand, the ability to accommodate changes in the spatial information of the ground truth data over fairly long periods of time but, on the other hand, the ability to order data over time scales of a few minutes to a few hours. These requirements are much more severe than are expected for urban GIS, but also more demanding than what users in other domains can probably live with. For example, even though change in natural environments occurs over small time intervals, if the applications are concerned with management of these changes then other constraints are likely to determine the "optimal" time units. In forestry, operations occur on an annual basis according to the seasons, and hence for many needs a temporal unit of resolution of a season or even a year may be acceptable.

Regardless of the temporal representation scheme adopted, one thing that is clear is that a fully dynamic GIS is needed to track the different temporal changes to the data base, especially for the management of remotely sensed data. By dynamic, we mean a GIS whose topology can be updated and interrogated immediately, without carrying out time-consuming and awkward batch rebuild operations on the data base or the spatial data structure. For

example, one would like to be able to modify an existing spatial data base by adding and deleting elements until the equivalent data base for a different date was obtained. This would be useful when working with images over several years. Presently, each year's ground truth map must be entered into a single, all-embracing data base as different "layers", involving a great deal of redundancy and increasing the load on the system, especially given the typically large size of such databases.

3. THE MANAGEMENT OF UNCERTAINTY: A KEY ISSUE FOR DYNAMIC GIS

Another issue which was briefly mentionned earlier is the question of uncertainty inside GIS. In section 2 above, it was indicated that in a vector-like temporal GIS, each object could be referenced temporally at the appropriate level of precision. However, although this is also considered a quality of vector data structures over raster in traditionaly spatial GIS, it is rarely exploited. Indeed, most spatial data is considered to be acquired at roughly equivalent spatial precision, once the spatial map scale has been determined. Only global errors are considered important, or even measurable. Boundaries are considered to represent the same level of precision. Although this is beginning to be questionned, no consistent way of using or even evaluating "local" spatial accuracy has been developed.

If temporal events are to be mapped, tracking temporal accuracy is likely to be even more important than for spatial data. Measurements in time usually cover very small durations. Time-filling measurements will be relatively rare, unlike "space-filling" measurements such as image pixels, where each measurement is an average over some spatial extent and there are no or few wholes in the coverage. There are object attributes for which a time averaging might occur, however. An example is the construction of a house. At what time does the house come into existence? Although individual measurements may take less than a second (e.g. image acquisition), the construction process takes some place over a period of several weeks. Hence locating the event at a given moment, down to the second, is ludicrous. The ability to handle "fuzziness" in time management is probably fundamental.

These considerations imply that at least temporal uncertainty must be managed in a dynamic GIS. Spatial uncertainty is also important. It has already been realised that, within existing GIS, it is all too easy to generate results which are meaningless. GIS usually contain many different "layers" of information. Analysis frequently consists of "overlaying" these layers and then recombining the results into newly meaningful entities. The difficulty arises when many layers are combined or when the results of one such overlay are combined with others. If each layer has some spatial uncertainty, simple error propagation rules tell us that this process will lead eventually to a situation where the results are meaningless. This can be frequently observed in practice by small polygons which result from many such overlays and which are not meaningfull (so-called "splinter polygons"). Furthermore, the significance of the results of such overlays are unknown since spatial uncertainty is usually unknown, since polygons boundaries are dealt with as precise even if their uncertainty is known and since error is not tracked anyway. Dealing with spatial analysis over time is likely to multiply such effects many-fold. For example, it is known in temporal modelling for growth and yield prediction in forestry that incremental modification of the database leads to increasing divergence between the models and the real data (Garcia, 1979). If results at several different times are to be meaningfully compared, evaluating errors in the original data, representing these errors and propagating them are necessary operations.

Furthermore, attempts to handle uncertainty in a global manner will usually fail to properly assess the significance of results. For temporal data, there is no reason to expect that objects of one type in one locality will have the same temporal uncertainty as objects at other

locations. The temporal uncertainty may itself change over time. Furthermore, it is becoming increasingly evident in some areas, such as forestry, that the mapping of natural phenomena involves variable uncertainty depending on the *local* properties of the entities being mapped.

A final area of some importance when interfacing remote sensing image analysis with GIS is the question of screening the results. This also is a complex topic, with many, sometimes conflicting, needs. First of all, GIS often are required to manage judicial or other information associated with map entities which have legal value and legal constraints. Also, erronous information derived from GIS, in some cases, may lead to court proceedings. Hence GIS should be able to "screen" incoming information and access to GIS should be limited to privileged users who understand the issues involved. (These are standard issues for all database management situations.) This is one reason why uncertainty should be better managed within GIS — if results were presented with an "error map", this would protect to some extent the data producers from misuse of the results. In addition, GIS might incorporate uncertainty thresholds, below which data is not accepted into the system.

These issues need to be thought out for remotely sensed data and image analysis. Some work has been done in the purely GIS arena on these and similar issues (e.g. Aranoff, 1989) but similar approaches need to be taken with remote sensing data and the results of image analysis. For one thing, if there is a conflict between the image data and the map data, which source should be considered correct? What if the map data has legal standing? (N.B. conflicts of this nature are *very* frequent, even prevelant, whenever image data is confronted with map data.) If local uncertainty were managed fully within GIS, perhaps such screening would be unnecessary, since error propagation would tell the user when results were very uncertain. However, a case can be made that some screening is always necessary, depending on the use to which data is put. For example, even if an image shows the appearance of a new house, this does not necessarily mean that a house should be added to the data base, if what the database is tracking is the legal existence of a house (i.e. the signing of the official documents which declare the existance of the building).

4. SYSTEM DESIGN ISSUES

GIS should be designed to incorporate, right from the beginning, an ability to screen data input. This might take the form of a knowledge-based "Update Manager" able to evaluate data (or metadata, data about data — see Bédard, 1990) in order to determine whether the data should be input to the GIS. In particular, such an Update Manager might require error information to accompagny the incoming data as a condition of acceptance. The Update Manager would serve three major functions: first of all, is the incoming data complete? secondly, does the incoming data meet the accuracy requirements of the GIS? and thirdly, is the incoming data consistent with the existing database? The latter is important for dealing with image-derived data which contradict existing data and also as a means of contraining proximity to existing objects and other internal management issues.

The management of temporal information implies the existence of an Archive Manager, able to store sequentially the entities which are added to or deleted from the database and the changes which are brought to attribute data over time. This Archive Manager would then be used as a mediator when it is required to recover the database at some earlier, historical epoch. This capability is crucial to the analysis of remotely sensed imagery, because proper validation requires the existence of so-called "ground truth" data or map data for each epoch at which the remotely sensed data is acquired.

Furthermore, a GIS which is designed to include remotely sensed imagery and the products of image analysis must be able to manage data at different levels of abstraction. Hence the GIS should be able to store (i) *image* data directly, in one specialized mode; to apply software to the image data and extract (ii) *processed image* data which would be stored in another specialized mode, along with metadata relating how it was produced; and finally the GIS would manage (iii) *generalized cartographic* data in another mode. The latter are what GIS manage today. The distinction between (ii) and (iii) is very important. Most "image products" produced by analyses of remotely sensed imagery today are not directly comparable with typical map-based information. The results of image analysis usually contain too much detail compared to cartographic information, which has been "generalized". While this difference is usually not recognized explicitly, the results of image analysis are frequently "cleaned" by ad-hoc filtering or some other operation before being incorporated into GIS. The existence of different "modes" of data within GIS also suggests the possibility of creating "intelligent" interfaces between each mode, as well as managing the metadata for each mode.

An example of what such a GIS, which incorporates all three modes of data as well as tracking uncertainty, might look like is illustrated in Figure 2. Present research by the author and collaborators at the Centre de Recherche en Géomatique at Laval University is tackling several parts of this structure. Members of the industrial research chair in geomatics applied to forestry are studying new dynamic data structures which support time management directly (Gold, 1991), the management of uncertainty (Lowell et al, 1992) and software for generalizing processed image data to produce cartographic data (Edwards, 1991). Other research at the Centre de Recherche en Géomatique includes the study of conceptual issues of time management (Gagnon et al, 1992), the use of metadata to characterise map and image information (Bédard, 1990) and the construction of an archiving manager (Gold). However, realistically, the development of such a system is still at least five years away, even in prototype, although pieces of it will probably become useful over the coming few years.

5. CONCLUSIONS

Several requirements for the management of remotely sensed data and analyses results inside GIS have been examined. Just as with the spatial characteristics, it is found that image management pushes the temporal behaviour of map entities in GIS to extremes. Also, the necessity of managing uncertainty is argued, both temporal and spatial uncertainty. An overview of the structure of a system able to carry out these different functions is presented. Some of the pieces of this structure are in place and new ones are under development at the Geomatics Research Centre at Laval University.

6. ACKNOWLEDGEMENTS

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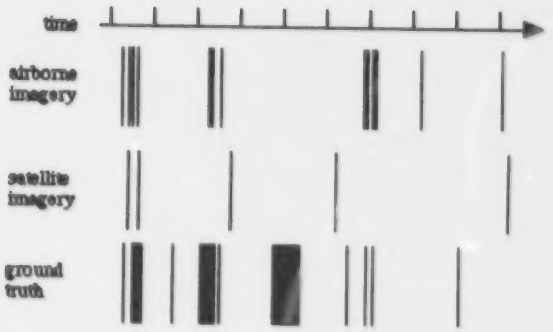

Figure 1: An example of typical timing for image events versus ground-based measurements for a long-term remote sensing campaign.

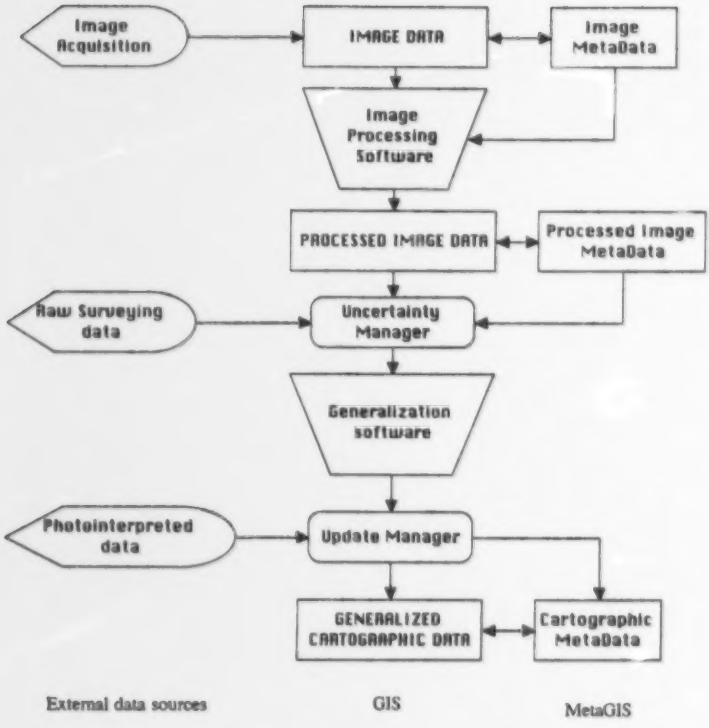

Figure 2: An example of the structure a GIS might take if it were to integrate remotely sensed data and the results of image analysis with existing cartographic data.

GIS for the 1991 Census Enumeration Area Spatial Database

MARK LEMAY

Abstract:

The 1991 Canadian Census will be supported by its first National Enumeration Area (EA) Spatial Database. This paper will highlight the process that help carved over 44,000 EAs. It will identify the traditional sources that help create the base and highlight there evolution within a GIS environment.

The role of GIS in the creation of the 1991 Digital Cartographic Library (CARTLIB). Why was the creation of the National EA spatial Database so important for CARTLIB 91.

Résumé:

La recensement du Canada sera supporté de sa première base national numérisée à l'échelle des secteurs de dénombrement (SD). Un contrendu des évènements et du processus qui ont permit d'assembler plus de 44,000 SD seront énumérés lors de la présentation. L'identification des sources traditionelles impliquées dans la création de la base et l'évolution dans un environment SIG.

Le rôle du SIG dans la création des fichiers de la librairie des limites cartographiques numérisées 1991 (CARTLIB). Pourquoi la création de la base numérique nationale des secteurs de dénombrement était si importante pour CARTLIB 91.

LABELLED ROAD NETWORKS
THE AMF PIECE OF THE GIS PUZZLE

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The GIS community at all levels of government and industry must recognize and come to grips with the need for a common spatial data infrastructure serving at least cadastral, street-level and land-use/land-cover applications, lest we continue to be communities of isolated, project-oriented map digitizers instead of a nation of GIS beneficiaries.

Where does Statistics Canada's Labelled Road Network, the Area Master File (AMF) - fit in the "big picture" of GIS? Is there a need for a national spatial data infrastructure?

The conversion of the national spatial data infrastructure from paper to digital form is gathering momentum. The closest thing to a general national spatial data infrastructure at the street block level of detail is the AMF, which - ironically - is essentially an internal working by - product of a statistical agency, not a mapping agency!

How else can our future spatial history be delineated?

RÉSEAUX ROUTIERS
LE RÉSEAU NUMÉRIQUE DE RUES CANADIEN
LE FPR DANS LE PUZZLE DU SIG

RÉSUMÉ

Les gens du SIG de tous les niveaux gouvernementaux et industriels doivent reconnaître la nécessité d'une infrastructure de données spatiales commune qui puisse avoir des applications au moins en ce qui touche les cadastres, les rues, l'utilisation des terres et les zones biogéographiques, sinon nous demeurerons des groupes de cartographes numériseurs isolés plutôt qu'une nation profitant des avantages du SIG.

Le fichier principal des régions (FPR) des réseaux routiers de Statistique Canada a-t-il sa place dans ce contexte général? Est-il nécessaire de posséder une infrastructure de données spatiales nationale? L'informatisation de l'infrastructure de données spatiales nationale commence à prendre de l'essor.

Le FPR est ce qui approche le plus, à l'échelle du pâté de maisons, d'une infrastructure générale de données spatiales nationale; l'ironie est qu'il s'agit essentiellement du sous-produit interne d'un organisme de statistique et non d'un organisme de cartographie! Peut-il en être autrement à l'avenir?

Labelled Road Networks
The Canadian Digital Street Network
The AMF Piece of the Puzzle

Does any of this sound familiar? The coordinates should be more accurate, more streets should be addressed, overpasses should be indicated, and what about one-way streets? Wait a minute - overpasses, one-way streets? The Area Master File is Statistics Canada infrastructure street network; the Bureau's job is to count heads.(1) It is these types of suggestions about improving our street network files that underpin the ideas in this paper.

The GIS community at all levels of government and industry is wrestling with the need for economic spatial data infrastructure serving cadastral, street-level and land-use/land-cover applications. This is occurring because in this information age properly organized spatial and geo-referenced information is a key aid in making decisions. All players in the Land Information System (LIS), Geographic Information System (GIS) and Geomatics communities know that we need to become a nation of GIS beneficiaries not communities of isolated, project-oriented map digitizers.

Statistics Canada's Geography Division Geocartographic Frame Data Base (GFDB) has a role to play in a national partnership for Geographic Information. Statistics Canada geographic infrastructure facilitates the comparability of statistical information relating to different parts of the federation. Dr. Ivan Fellegi, the Chief Statistician of Canada has said that provinces need comparable information to use as a currency of analysis and that comparability is an even more important requirement by the business sector whose operations- and hence information needs do not respect jurisdictional boundaries. (2)

This paper discusses our spatial challenges by discussing the following questions:

1. Is the conversion of the national spatial data infrastructure from paper to digital form really gathering momentum?

2. Where does Statistics Canada's labelled road network the Area Master File (AMF) - fit in the "big picture" of GIS?

3. Is the AMF a catalyst for a national spatial data partnership at the street block level of detail?

4. Are there opportunities for a national spatial data partnership?

5. **Can we build a strategy for a Canadian Digital Street Network (CSDN)?**

6. **Do we need an umbrella organization for the whole geographic information community?**

1. From Paper to Digital

In 1970, the national spatial data infrastructure consisted of the nation's paper-map inventory, containing Federal and Provincial mapping and survey "topo" series, census and military maps, and various nautical and aeronautical charts. But in the past 20 years, Canada has move a long way toward managing information by machine. Virtually all financial data and most large-scale word processing is computerized; because of its peculiar complexities, spatial data is one of the last areas for automatic computerization.

The conversion of the national spatial data infrastructure from paper to digital form is gathering momentum. In May 1991 the Inter Agency Committee on Geomatics released the Directory of Federal Digital Geographic Data in Canada.(3) Several criteria were defined as important in selecting data holdings to be included in the directory. The criteria used tells a lot about how far we have gone on the road from Paper to Digital. These criteria talked about information where:

> The data set must be directly georeferenced. That is, it must be able to be related directly to coordinate framework, references to which are part of the data set. Examples of such data sets included maps, charts, atlas sheets, remote-sensing, imagery or statistical data related to coordinate points, but not data related only to street addresses, postal codes, or other nomina codes.
>
> The data set must be at a scale smaller than 1:500,000 i.e. it must have been derived from document drafted at that or larger scale. Large-scale plans such as engineering drawing and other detailed maps are not included. A 1984 survey defined the scales of interest as 1:10,000 and smaller.
>
> The data set must be in digital form now, or must be in the hard copy form now with plans to convert to digital form before the year 2000 if they include some part of Canada as defined.

The May 1991 Directory of Federal Digital Geographic Data in Canada found 314 data holdings that met these criteria.

Another example of this transition to digital can be found in the land registry operations in Ontario. In that province the newly created TERANET Land Information Services Inc. is implementing a computer based technology which organizes and manages data related to parcels of land and related that data to ownership information. TERANET describes its challenge as one where the paper bases methods and systems in Ontario for recording land ownership and geographically related information have been antiquated and inefficient.(4) They see their digital LIS as changing all that.

2. Statistics Canada's street network file, the Area Master File (AMF) and the "big picture" of GIS?

Statistics Canada digital street network, the Area Master File (AMF) is a digital data file stored in computer readable format, which defines the complete street network and other physical and cultural features within a specific geographic area, usually a census subdivision. AMFs are presently created and updated for municipalities with 50,000 population and over.

The street network files were first developed for the 1971 Census to meet client demands for custom small area data retrieval within large urban areas. The AMF is a topologically consistent feature file by municipality. It consists primarily of linear features (streets, hydrography, limits, railways, etc), each with feature names, and for each block along the features a record of cross streets, x-y coordinates in UTM, and the range of addresses. The street network files references every street, address range, blockface and centroid coordinate and itemizes other features such as rivers, railroad tracks and municipal boundaries. Total AMF coverage is now about 340 municipalities comprising 1,500,000 records and covering 60% of the Canadian population.

Within Statistics Canada, AMFs have become not only the base for geocoding, but also the base for defining most standard geographic areas and cartographic operations.(5) For the 1991 Census, the Geography Division has started to integrate the street network file and all its other geographic reference materials into a single central database for built up areas.

3. The AMF a catalyst for a national spatial data partnership

Can the AMF be a vehicle for a national spatial data partnership at the street block level of detail?

The AMF's reception by municipalities, provincial governments and by the private sector indicates it could be a vehicle for a national spatial data partnership. The AMF provides significant pan Canadian urban coverage, functions as a rough cartographic database and contains links to data that are geo-located only by street address. All of this goes well beyond the minimum external need to define statistical zones for census data users. The AMF is used by a wide variety of public and private organizations.

As I said earlier along with enthusiasm for the AMF come complaints: the coordinates should be more accurate, more streets should be addressed, overpasses should be indicated, and what about one-way streets?

It is within this world of complaints that I see the potential for partnership. The fact remains that the AMF has often been the first step in the creation of spatial data infrastructure at the street block level of detail.

It is also a sign of fast our changing electronic information world that the AMF is a product of a statistical agency and rather than a mapping agency!

4. Opportunities for a national spatial data infrastructure?

National, provincial, regional and local organizations are working towards developing individual digital street network databases which can be used for a multitude of purposes. Several players have the potential to monitor changes and growth areas across Canada.

Canada Post, Elections Canada, Energy Mines and Resources, Environment Canada are logical partners for building and maintaining digital street networks in Canada. They could also be strategic partners in the creation of street networks for those municipalities not covered by the AMFs. A wider partnership could also include facilitating the consolidation of cadastral information, street networks, addresses and postal codes in an integrated LIS-GIS-Geo-Postal system.

Future Opportunities

- Statistics Canada needs digital street networks to support Census and Survey operations and already has digitized cities which in total cover 60% of the country's population.

- Canada Post Corporation has a similar requirement to support mail operations and marketing and sales. CPC has a structure in place to monitor changes and growth within Canada.

  Elections Canada and the provincial and municipal electoral authorities have similar requirements for voters lists, address lists (data), and electoral maps (cartographic layer)in a GIS environment.

- Municipalities, regional governments and provincial agencies would also be data providers and user partners as they too have operational needs for digital street networks.

- By examining the feasibility for combining our requirements and by examining the business case for a partnership, we may have an opportunity to reduce costs, and to improve data quality, currency and coverage.

5. Partnership for a Canadian Digital Street Network (CSDN).

The road to building a Canadian Digital Street Network involves:

- Investigating the impact and opportunities of integrating Canada Post's, Election Canada's and Statistics Canada's business plans with the objective of producing a partnership for a Canadian Digital Street Network.

- Undertaking the analysis, developing a prototype and performing tests that satisfy the requirements of the agencies with respect to street networks.

- Integrating business plans to capitalize on the resources of both agencies.

- Performing the transition to an integrated production environment.

The Geography Division at Statistics Canada in the last year has arrived at to the first stage of a CSDN by talking with potential partners.

6. An umbrella organisation for the whole Canadian geographic information community?

A street network partnership will also prosper if we build a Canadian Association for Geographic Information. No all embracing association is sitting on Canada's shelf today. One paradigm for an industry wide association can be found in the UK. David Rhind has described the key distinctive contemporary features of GIS in the UK as:

> the 'pseudo-commercialisation of data and information by government;
>
> the trend towards a user-driven business, rather than one driven by data providers;
>
> the success of collaboration between different interests, much of it mediated through the Association for Geographic Information; (6)

In Canada we to are commercializing data and information. We are following the trend of being in a user driven business. However we lack an Association for Geographic Information. We do not have an umbrella organization for the whole geographic information community. We have several exclusive clubs but no all embracing Canadian organizations at the provincial or national level.

On January 1, 1991 the UK Association for Geographic Information membership stood at 500 of which more than half were individuals. Their membership both individual and organizations, is drawn from over twenty different industry sectors. These include: local government; central government; education research, institutions societies; financial services; property; emergency services; data capture and conversion; marketing, and data broking.

GIS in the 90's can give us a Canadian Digital Street Network and much more. We can get the best network if GIS/LIS finds an inclusive home.

End Notes

1. Donald Cooke wrote on this theme about the USBC's Tiger File in GIS World, May 1991

2. The Canadian Statistical System- A Centralized Model, Ivan P. Fellegi, Chief Statistician of Canada, February 1991.

3. The Directory of Federal Digital Geographic Data, The Inter Agency Committee on Geomatics, May 1991.

4. Teranet Land Information Services Inc. Brochure 1991.

5. GIS Tools for the 1990's, Grafton Ross, Joel Yan, Richard Nadwodny, May 1990.

6. Breakthroughs in GIS? A British Perspective, David Rhind, The Canadian Conference on GIS, March 18-22, 1991.

EVOLUTION OF THE UNITED STATES / CANADA COMMON BORDER DATABASE

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Abstract

The Common Border Database research project, a cooperative venture of the Geography Divisions of Statistics Canada and the United States Bureau of the Census released two prototype boundary file products in the fall of 1991. The files, one of the Detroit / Windsor street network and the other containing limits of the south-central Canadian Census Divisions and northeastern United States Counties, are intended to evaluate the potential for a variety of North American research projects.

The uniform nature of the files, their embedded attributes and most importantly their linkages to the immense census data sets make them ideal bases for GIS analysis and mapping in support of a great variety of cross-border research applications.

The paper discusses applications of the Common Border Database products already in progress and anticipated enhancements based on preliminary user feedback.

ÉVOLUTION DE LA BASE DE DONNÉES FRONTALIÈRES CANADO-AMÉRICAINE

RÉSUMÉ

La recherche sur la base de données frontalières canado-américaine, projet conjoint des divisions de géographie de Statistique Canada et de l'USBC a produit deux prototypes de fichiers de données frontalières en automne 1991. Ces fichiers, dont l'un porte sur le réseau de rues de Détroit/Windsor et l'autre sur les subdivisions de recensement du centre sud au Canada et sur les comtés du nord-est des États-Unis, doivent servir à évaluer le potentiel de divers projets de recherche de géographie nord-américaine.

De par leur homogénéité, la permanence de leurs caractéristiques et surtout leurs liens avec les énormes ensembles de données que constituent les recencements nationaux, ces fichiers sont des bases idéales pour des travaux d'analyse et de cartographie à partir de données de SIG dans le cadre de travaux de recherche canado-américains très variés.

Dans cette présentation, il est question des applications des produits de la base de données frontalières déjà en réalisation et des progrès escomptés en raison de l'amélioration des bases géographiques des deux divisions et des premières réactions des usagers.

1. INTRODUCTION

In the period between the collection dates of the United States' Census of Population (April, 1990) and the Canadian Census of Population and Housing (June, 1991), the concept of a Common Border Database that would offer an integrated version of the two nations' census geographic boundaries emerged. Victor Glickman, Director of the Geography Division, Statistics Canada and Robert Marx, Chief of the Geography Division, United States Bureau of the Census (U.S.B.C.) agreed that a project to explore and develop the idea should begin. This paper discusses the progress and plans completed to date, beginning with the concept's rationale.

The motive for the project can be seen as a response to changes of the context in which geographic networks are viewed and used. In addition to the internal need for a geographical perspective of each nation's census information there is a growing interest in the interrelationships between the microscopic as well as macroscopic activities in each nation. A Common Border Database should facilitate cross-border spatial analyses of data concerning, for instance, small communities separated by the border as easily as national statistics have long been compared. Origin and destination cross border flow mapping would be made easier by the unified source of geographic information. The project may also assist data compilation unrelated to border issues. For instance, micro-scale research into environmental issues ought not stop at our cultural border. The ability to map and visualize common border data is an added benefit of the project.

The Common Border Database is to provide a convenient, unified geographical framework for these purposes. Apart from containing geographic boundaries within each country, a main strength of the Common Border Database concept is that it provides a unified linkage mechanism to each nation's wealth of geographically referen-

ced statistical data. While these information sources will always remain independent, the Common Border Database concept provides, for instance, a single source for user-compiled lists of linkage codes for any user-defined polygon. This is now possible regardless of the country in which the statistical area is found.

Given this rationale for creating a unified Common Border Database, initial efforts have resulted in two prototype products and the formation of a mechanism for gaining feedback from each agencies' user communities about possible directions for continuation and expansion of the project.

2. PROTOTYPE DATA SETS

The two prototype products differ in content and coverage. A regional prototype is a unified geographic base with a linked statistical data set for part of the Northeastern U.S. and South Central Canada containing Canadian Census Division and U.S. County boundaries. The regional approach was chosen to limit the product to a manageable size during development of the concept and techniques (Figure 1). Nevertheless, it does include about half of Canada's population (including Québec, Montréal, Ottawa-Hull, Toronto and Windsor) and roughly one quarter of the U.S. population (including Detroit, New York, Boston, Philadelphia and Buffalo).

A local prototype product contains the detailed street network for Detroit and Windsor. The U.S. portion of this prototype does not extend to the limits of the Detroit - Ann Arbour Consolidated Metropolitan Statistical Area, nor even the Detroit Primary Metropolitan Statistical Area. Instead, it only includes Wayne County (which contains Detroit). Even though digital boundary data are available for all U.S. counties, this restriction was imposed to

permit a rough equivalence with the Canadian portion, which must be limited to the Census Subdivision (CSD) of Windsor because that is the limit of the digital street network file coverage. Equivalent files have not yet been assembled for the surrounding CSDs that form the Windsor Census Metropolitan Area.

The agreement between the two agencies provides for continual consultation and cooperative Common Border Database product construction, planning, marketing, and improvement. Actual work necessarily happens in one or the other of the two organizations, and the construction of the prototype products has been undertaken by Statistics Canada with its own data and TIGER files provided by the United States Bureau of the Census.

Both prototypes, and indeed plans for future products, involve accurate alignment of boundaries at the legal international border. These coordinates, and other aspects of the world's longest (8963 Km) two-nation frontier, are maintained by the International Boundary Commission (I.B.C.). The 11,463 geographic coordinates describing the legal boundary provided to the project by the I.B.C. were used to define the border between Canada and the United States. An interesting aspect of the boundary is that while almost all courses between pairs of surveyed turning points are great-circle lines, two special courses, one in Lake Ontario and one in Lake Erie legally consist of true east-west lines. The nominal surveyed coordinate precision of 0.001 seconds (better than 32 mm precision) is unusual for statistical GIS purposes in that it is thought to represent the real boundary accuracy. A spin-off benefit of the Common Border Database project is the two agencies' agreement to standardize future boundary networks to the same coordinate set.

The differences between the two agencies' boundary sets provided interesting challenges during the prototypes' construction. Statistics Canada's urban networks, the Area Master Files (AMFs), have

greater statistical linkage resolution than the United States Bureau of the Census TIGER files because their elemental units are blockfaces. The TIGER/Line files contain feature information for each line, but only reference the lowest census statistical area information by whole blocks. On the other hand, TIGER information is nation-wide while AMF coverage of urban areas comprises only 60% of the Canadian population and less than 1% of the land area. In order to have a Common Border Database product with as uniform a structure as possible, the Canadian blockface data linkages are avoided in favour of a higher level of geographic linkage through Census Tracts, which tend to be common for several contiguous blocks and are fairly equivalent to U.S. Census Tracts.

The prototype data sets were assembled into ARC/INFO coverages at Statistics Canada. The preparation of the Canadian components of the prototypes was straight-forward because the boundaries had been built and maintained in ARC/INFO. Conversion of the approximately 720 U.S. County TIGER files falling within the regional prototype box was a more difficult task. While an ARC/INFO command, TIGERARC, exists for TIGER file import, it can only be used to build entire county coverages. A county-by-county process of building complete county coverages while eliminating internal features would have involved prohibitive computation costs. Instead, a method of only extracting county boundaries had to be developed. A program was written for a PC to filter the boundary limit features directly from the TIGER/Line CD-ROM. The boundary limits of coastal counties extend offshore; in these cases additional hydrological features were extracted and edited to provide the land coverage desired. Operational constraints influenced the decision to include offshore islands in the coverage but to exclude internal lakes. County identification labels were attached to every polygon as they were amalgamated into a single ARC/INFO coverage forming the U.S. portion of the prototype.

The Windsor portion of the Detroit-Windsor prototype was compiled with the ARC/INFO AMFARC utility. An optional non-filtering feature of the PC program was used to assemble the Wayne County portion. The majority of each file's coordinates remain unchanged but alignment near the border was necessary. Both files contain a line near the middle of the Detroit River. These were replaced by the I.B.C. border. Occasional lines extend from shores to these middle lines. These were extended along the same direction or shortened as necessary. Arcs describing the two halves of the Ambassador Bridge missed by about 30 m in midstream. These were replaced by a new arc joining the original shore points (Figure 2). Similar alignment was performed along the entire regional prototype border.

The ARC/INFO coverages were then converted with a custom program into pseudo-TIGER/Line files that conform to the TIGER/Line Type 1 and Type 2 coordinate files. The TIGER/Line coordinate format is line-based, and codes identify the polygons on each side of every line feature. A polygon attribute file contains information about each geographic unit. While the most important attribute information in the Common Border Database prototypes is the census linkages polygon areas, population and dwelling counts have also been included. These can be used for a number of applications including per-capita or area density mapping of associated data. The files were then sent to the United States Bureau of the Census for publication on CD-ROM. The CD-ROMs were packaged with maps and accompanying documentation.

3. PROTOTYPE EVALUATION

The first two Common Border Database prototype products are available free of charge to any interested party who agrees to provide feedback. Kits have already been distributed to a number of

geographers and other prospective users who were thought to have related interests. Other prospective users need only contact the authors. The data and accompanying materials are contained on a CD-ROM, available on request from either agency.

As useful as it is hoped that the Common Border Database prototypes are, their main purpose is to obtain feedback from potential users that will help us direct future development of more ambitious and helpful products. What are wanted from users are ideas about the most important geographic areas to focus on, the means of distribution, the type of boundaries, the linkages to associated data, distribution file formats, and so forth. We also want to know how geographers may have used or plan to use the prototypes, and what uses they might imagine for future products.

4. FUTURE PRODUCTS

Ideas for the future of the Common Border Database project are largely in the hands of the users. As service organizations, both agencies are committed to providing high quality products that are as useful as possible to researchers or other interested parties. While feedback is awaited, the following enhancements already are being considered. Firstly, the geographic extent ought to be increased to include all of the U.S. and Canada. Consideration is being given to the idea of incorporating suitable geographic units in the United States of Mexico to make a North American Common Border Database that would consist of a joint contribution to the Administrative Boundaries of the World Project as well as increasing the usefulness of the Common Border Database concept to general users. Other urban products such as a Toronto to Buffalo Common Border Database or a Vancouver to Seattle Common Border Database might take shape. Looking further ahead, Statistics Canada will soon be releasing its 1991 Census Enumeration Area

(EA) Boundaries (which roll up to all higher standard geostatistical units) for the entire nation. In addition, existing and future AMFs will eventually be integrated with the EAs to form one national database that will match the width of coverage, if not the rural detail, of the U.S. TIGER files. These changes will gradually permit the Common Border Database project to produce more and more elaborate products. The next generation products will inevitably capitalize on improvements in the U.S. boundaries as well. The alternative TIGER products such as TIGER/Boundary from the 1990 decennial census, for instance, will become available for Common Border Database and other uses.

The same factors which influenced the initiation of the project, that is the growing need for harmonized geographic products facilitating integrated data research may trigger expansion of the current aims from a bilateral project to a more international one. There exist other projects like the Digital Chart of the World that present international geographic boundaries, but the Common Border Database is the only project that achieves this resolution and this linkage to census data.

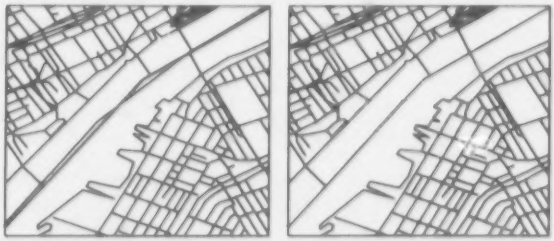
TABLE 1: REGIONAL PROTOTYPE SPECIFICATIONS

EXTENT description:	39°N to 48°N, 70°W to 93°W.
GEOGRAPHIC UNIT:	(Canada) Census Division; (U.S.) County.
BOUNDARY SOURCE:	(Canada) Statistics Canada CARTLIB files; (U.S.) U.S.B.C. TIGER/Line Precensus files.
BOUNDARY DATA:	(Canada) manually digitized Energy Mines and Resources, Canada 1:50,000 and 1:25,000 topographic maps; (U.S.) certified boundaries from local officials as part of an annual Boundary and Annexation Survey Program.
CENSUS LINKAGES:	(Canada) 1986 Census of Population Census Division codes; (U.S.) 1990 Federal Information Processing Standard State and County Codes.
INCORPORATED DATA:	Polygon areas; (Canada) 1986 population and dwelling counts; (U.S.) 1990 population and dwelling counts.

TABLE 2: LOCAL PROTOTYPE SPECIFICATIONS

EXTENT description:	Windsor, Ontario and Wayne County, Michigan limits.
GEOGRAPHIC UNIT:	Blocks of street and other visible features.
BOUNDARY SOURCE:	(Canada) Statistics Canada Area Master File; (U.S.) U.S.B.C. TIGER/Line Precensus file.
BOUNDARY AND FEATURE DATA:	(Canada) manually digitized maps of scales ranging from 1:1000 to 1:24,000 provided by the Metropolitan Windsor Planning Department; (U.S.) TIGER files that contain automatically scanned U.S. Geological Survey 1:100,000 topographic maps as well as other features and updates. In additional copyrighted source information was added to the TIGER database from AAA Detroit Western and Southern Suburbs map.
CENSUS LINKAGES:	(Canada) 1986 Census of Population Census Tract codes; (U.S.) 1990 Census of Population Census Tract codes.
INCORPORATED DATA:	Polygon areas; (Canada) 1986 population and dwelling counts; (U.S.) 1990 population and dwelling counts.

Regional Prototype Coverage
Figure 1



Two sources & border

Aligned at border

Detroit-Windsor Prototype alignment
Figure 2

GEOGRAPHIC INFORMATION SYSTEM BASED MULTI-DIMENSION AGRICULTURAL LAND RATING ON REGIONAL BASIS

by

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ABSTRACT

Most agricultural land rating schemes are based entirely upon the physical properties of land, while a few upon economic characteristics. Although understanding resource base and economic features is essential in agricultural land-use planning, a single-dimension approach to land rating is inadequate, because only a limited number of variables are considered. Instead, a multi-dimension approach is more encompassing as it emphasizes a spectral outlook in analyzing the relative importance of land for cultivation. However, such an approach induces more burden for creating flexible systems of data imputation, manipulation, and presentation. Consequently, an information system which is capable of dealing with the above problem is needed. This paper was aimed at highlighting the use of Geographic Information System (GIS) in integrating technical, economic/geographic, and planning dimensions into a framework of agricultural land rating on a regional basis in Malaysia. Maps were constructed using GIS techniques to be used as a tool for interpreting the framework and decision making. The ultimate outcome was a regional map showing the distribution of appropriate area to be devoted to cultivation of various crops according to the land's relative importance. It was disclosed that, although the process was complex, the approach has managed to improve the decision methodology in allocating land for regional agricultural cultivation in Malaysia.

CLASSEMENT MULTIDIMENSIONNEL DES TERRES AGRICOLES PAR RÉGIONS AU MOYEN D'UN SYSTÈME D'INFORMATION GÉOGRAPHIQUE

RÉSUMÉ

La plupart des classifications des terres agricoles sont exclusivement basées sur les propriétés physiques du sol et quelques-unes, sur des caractères économiques. Il est important de comprendre les ressources et les caractères économiques dans la planification de l'utilisation des terres agricoles, mais une classification unidimensionnelle n'est pas indiquée, car on ne considère qu'un nombre limité de variables. L'approche multidimensionnelle est plus complète, car elle procède essentiellement d'une vue élargie dans l'évaluation de l'importance relative des terres en agriculture. Avec une telle approche, toutefois, la création de systèmes souples pour l'introduction, la manipulation et la présentation de données demande plus de travail. Il faut donc un système d'information qui permette de régler ce genre de problèmes. Cette présentation porte sur l'utilisation d'un système d'information géographique (SIG) pour intégrer les aspects techniques, économiques, commerciaux, socio-géographiques ainsi que la dimension de la planification dans un cadre de classification des terres agricoles régionale en Malaysia.

Le SIG a été employé à la constitution de cartes servant à interpréter le cadre de classification et à prendre des décisions. Le résultat final est une carte régionale représentant la distribution de la superficie appropriée pour diverses cultures, en fonction de l'importance relative des terres. Ce procédé, bien qu'il soit complexe, a permis d'améliorer la méthodologie décisionnelle gouvernant la répartition des terres pour l'agriculture régionale en Malaysia.

Cartographie écologique des milieux littoraux des Iles-de-la-Madeleine

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Résumé

La division de la gestion de l'habitat du poisson du ministère des Pêches et Océans du Canada vise, à long terme, à mettre sur pied un système informatisé d'aide à la décision permettant une planification intégrée de la gestion des ressources halieutiques. Cette gestion des ressources est basée sur une connaissance intégrée des différentes composantes biotiques et abiotiques des écosystèmes, nécessite l'accès à un inventaire aussi complet que possible des ressources et est facilitée par une cartographie du milieu en zones écologiques homogènes.

Un projet pilote est réalisé dans le secteur des Iles-de-la-Madeleine. L'inventaire des ressources du milieu côtier a conduit à subdiviser le territoire des îles en 17 zones écologiques homogènes définies à partir de facteurs stables (topographie, bathymétrie,...) et dynamiques (vents, marées, végétation,...) de l'écosystème. L'information relative à ces systèmes côtiers est gérée par un SGBD relationnel (Oracle) qui permet d'acheminer rapidement et de manière souple cette information de base dans un système d'information géographique (Spans) en vue d'une analyse et d'une modélisation spatiale. L'utilisation d'un certain nombre de clés d'interprétation conduira à une cartographie du territoire selon des thèmes tels que la sensibilité ou le potentiel du milieu.

Ecological Mapping of Coastal Environments, Îles-de-la-Madeleine

Abstract

A long-term objective of the Fish Habitat Management Division of the Department of Fisheries and Oceans of Canada is to establish a computerized decision-making aide that allows integrated planning of fish resource management. This resource management is based on an integrated knowledge of the various biotic and abiotic components of the ecosystems; it requires access to an inventory of resources that is as complete as possible, and is facilitated by environment mapping that indicates homogenous ecological zones.

A pilot project is being conducted in the Îles-de-la-Madeleine sector. Preparation of the inventory of coastal environment resources has involved subdividing the islands' region into 17 homogeneous ecological zones defined on the basis of stable factors (topography, bathymetry and so on) and dynamic factors (winds, tides, vegetation and so forth) of the ecosystem. The information on these coastal systems is managed by a relational DBMS (Oracle), which allows rapid, flexible routing of this basic information within a geographic information system (Spans) for analysis and spatial modelling. The use of a number of interpretation keys will permit mapping of the region in accordance with themes, such as environmental sensitivity or potential.

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DIGITAL PROPERTY MAPPING IN NEW BRUNSWICK

Abstract

The New Brunswick Geographic Information Corporation currently maintains in hard copy format a complete representation of the cadastral framework consisting of 450,000 land parcels for the entire province. A 3 year program has been established for the conversion of these parcels to digital format ready for use at GIS sites.

This paper will present an overview of the program focusing on the strategic alliances formed to share in the cost of the conversion program, the standards used for digital conversion, the maintenance of the digital property map files, the pricing policy for the data and the distribution of the digital files.

Résumé

La Corporation d'information géographique du Nouveau-Brunswick maintient sous forme conventionnelle la représentation cadastrale pour l'ensemble de son territoire comprenant 450,000 parcelles. Un programme de 3 ans pour la numérisation des cartes cadastrales a été établi ayant pour but que les données soient utilisées par des systèmes d'information géographique.

Cet article traitera des alliances formées pour partager les coûts de ce programme, les normes utilisées pour la numérisation, la mise à jour de ces fichiers, les principes pour établir les coûts des données ainsi que la distribution de ce produit.

1. BACKGROUND

The New Brunswick Geographic Information (NBGIC) maintains in conventional hard format a cadastral representation referred to as property maps for the entire Province. The property maps are maintained in the 5 Land Information Centres of the Corporation strategically located throughout the Province. These offices are located in Bathurst, Edmundston, Fredericton, Moncton and Saint John each one being responsible for a specific geographic area.

In June 1990, a report prepared by the Task Force on Urban Mapping recommended that the New Brunswick Geographic Information Corporation undertake a program for the digital conversion of its property maps. The Task Force on Urban Mapping was composed of representatives from the Champlain Institute, Municipalities, NBTel and NB Power.

It was also widely recognized that this program would stimulate the growth of the Geomatics Industry in the region. Business opportunities would also be created from the availability of the digital property map files.

This project was identified as a strategic project with a high priority in the business plan of the Corporation. A project team was established in October 1990 to coordinate this project. It was targeted from the outset that the digital conversion activity would be completed for the entire Province by March 31, 1994.

2. ACTIVITIES

The digital property mapping project consists of three major activities:

- Digitizing the existing conventional property maps to create digital property map files.
- Establishing a maintenance program for the digital property map files.
- Establishing the procedures for distributing the digital property map files in both digital and hard copy format.

3. DIGITAL CONVERSION

As of October 1991, there was in the order of 450,000 parcels in the Province. This increases at an approximate rate of 2.4 % per year. This cadastral representation is shown on 5500 conventional property maps. Initial estimates indicated that it would cost in the order of $2.2 to 2.4 million in contracts to industry to complete the digital conversion of property maps for the entire Province.

The report by the Task Force on Urban Mapping recommended that the Corporation pursue partnership agreements in order to share in the cost of the program. It was recommended that the cost of the digital conversion could be shared as follows:

NBGIC	40%
NB Power	20%
NBTel	20%
Municipalities & Planning Commissions	20%

Partnership agreements in the value of 20% of the cost for their respective areas have been reached with the City of Edmundston, City of Fredericton, City of Moncton and the City of Saint John. In return they will receive a copy in digital format of the digital property map files and updates at no costs until March 31, 1996.

A partnership agreement was reached with NBTel where they will digitize 20% of the parcels in the Province in return for all the digital property map files covering the Province. A similar partnership agreement was recently reached with NB Power. It will be formalized in the near future.

A three year plan for the digital conversion of property maps has been established in consultation with the partners. Emphasis was placed on completing logical areas such as Cities, areas covered by Planning Commissions and Counties. Figure 1 contains the details of the number of parcels to be digitized in each county by fiscal year.

Request for proposals for the digital conversion of property maps are forwarded to companies who have successfully completed an eligibly test. Nine companies have now successfully completed this eligibility test.

In the 1991/1992 fiscal year the digital conversion of 166,100 parcels was undertaken, of these parcels 109,200 were contracted to private industry at a cost of $455,600.

3.1 STANDARDS

Specifications for the digital conversion of property maps were established. The resulting digital property map files are topologically structured and ready for use at GIS sites. The specifications were tailored to make effective use of the CARIS data structure. It should be noted that CARIS is the GIS standard used by the government of New Brunswick.

Selected features from the 1:10,000 digital base map files are used when the property maps were compiled at a similar scale, there are currently no large scale digital base maps available in urban areas.

The standard digital property map file was defined in terms of a management unit as shown in figure 2. The underlying principle to a management unit is that a property is contained within only one management unit; the limits of the management unit are irregular in shape. Approximately 2000 parcels are contained in a management unit. Assembling these files provides for a continuous seamless database of the Province.

From a data management perspective there will be in the order of 250 management units to cover the entire province compared to 5500 conventional property maps. The digital property map files are delivered by the Contractors in a CARIS NTX format at a 5 centimetre resolution.

Standards were established in the preparation of contracts and manuscripts. This is especially important in the preparation of digitizing instructions to the contractors as this is done by the various Land Information Centres. It also ensures that contracts from different Land Information Centres have a similar content.

Procedures were established for the quality control of the deliverables and the various command procedures are forwarded to Companies with contracts to minimize the problems with the delivered product.

3.2 LAND INFORMATION CENTRES

The Land Information Centres of the Corporation are responsible to prepare the information for contracts. This includes the preparation of special digitizing instructions for each manuscript. It is estimated that 4 person days per 1000 parcels are required in the preparation phase.

After contracts are awarded a staff member of a Land Information Centre becomes the Inspector for the contract and the only person dealing with the contractor on behalf of the Corporation for this contract.

All five Land Information Centres and the Development Section of the Corporation have acquired CARIS PC on 486 microcomputer. The operating system in keeping with the government policy on open systems is SCO ODT. Staff from all offices were trained in Unix and CARIS, this training was done in the private sector.

4. MAINTENANCE

Procedures for the maintenance of the digital property map files have been established. An implementation plan is being formulated and it is expected that it will be fully implemented by July 1, 1992.

Provincially there are in the order of 6200 graphic transactions to update the property maps per year. A transaction may involve the alteration and addition of one or several parcels. It is expected that users will be supplied with transaction files containing adds and deletes. This method of updating users will avoid large data transfers and provide the opportunity to keep client databases as current as possible.

5. DISTRIBUTION

A pricing policy is being formulated by the Corporation to provide for an appropriate distribution mechanism to all clients including valued added services and multiple users of the same databases. It is expected that this pricing policy will be available in 1992.

The digital property map files are made available through partnership agreements as previously explained or by direct sale at a cost of $0.65 per parcel with incidental costs for media and interchange formats. Acquiring digital property map files through partnership agreements gives the user free updates until March 31, 1996. To enter into a partnership agreement the users pay 20% of the conversion cost.

Procedures are being developed for the distribution in digital format in various user defined windows. The distribution of the digital property map files in hard copy format will be formulated in conjunction with the Land Records Management Project of the Corporation.

6. CONCLUDING COMMENTS

This project has stimulated the growth of the geomatics industry in the region. It has allowed companies to get involved in data conversion and had offered business opportunities for others in developing applications with this data and value added services. Stimulating the growth of the geomatics industry is one of the objectives of the New Brunswick Geographic Information Corporation.

This project has allowed to build GIS expertise within the Corporation and the private sector. Several companies involved in the data conversion are now pursuing other related applications with this data.

The spirit of cooperation in reaching the various partnership agreements was essential in securing the commitments and funding to undertake this program.

REFERENCES

McLaughlin, John et al [1990]: Towards an Urban Digital Mapping Program. Urban Task Force on Urban Mapping.

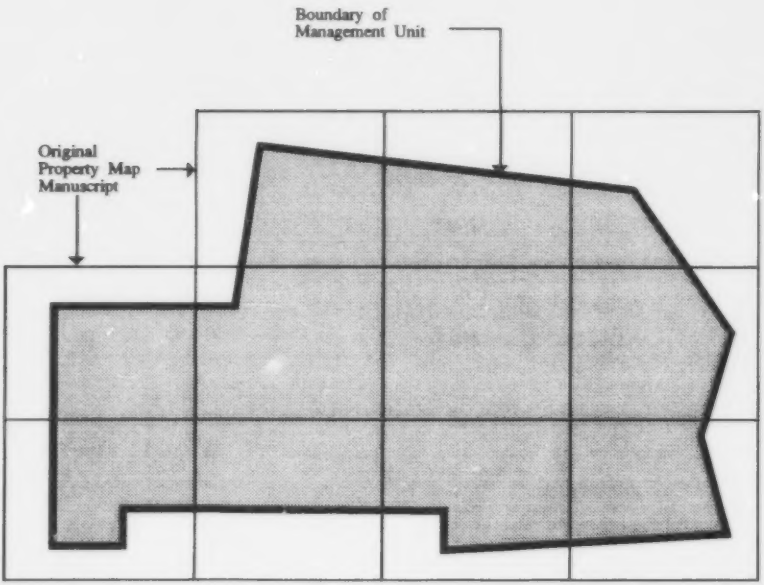
Figure 1

Digitizing Schedule by County

County	FY 1991/1992	FY 1992/1993	FY 1993/1994	Number of Parcels
Albert	15,100	0	0	15,100
Carleton	0	19,600	0	19,600
Charlotte	0	0	21,300	21,300
Gloucester	33,400	29,300	0	62,700
Kent	0	29,200	0	29,200
Kings	0	37,200	0	37,200
Madawaska	24,500	0	0	24,500
Northumberland	0	0	38,000	38,000
Queens	0	7,200	5,900	13,100
Restigouche	0	22,300	0	22,300
Saint John	26,400	4,100	0	30,500
Sunbury	0	11,300	0	11,300
Victoria	0	15,400	0	15,400
Westmorland	36,700	26,200	0	62,900
York	30,000	15,700	0	45,700
Total	166,100	217,500	65,200	448,800

FIGURE 2

THE MANAGEMENT UNIT CONCEPT



Management Units

- Composed of portions of original property map manuscripts
- Limits are defined by parcel boundaries.
- A land parcel is fully contained within a management unit
- Approximately 2000 parcels per management unit.

Identifying the Conservation Gap: a Case Study of Northern Thailand

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Abstract

Although Thailand's protected area system is extensive, its adequacy is unknown. Its adequacy is unknown because there has been no systematic assessment of the distribution of species relative to protected areas. Without such information, it is difficult for conservation planners to determine conservation priorities. One method for collecting this kind of information and establishing priorities is called Conservation Gap Analysis or CGA. The objective of this assessment is to produce a map of the spatial distribution of species in relation to protected areas.

This paper describes a CGA for Northern Thailand that was carried out using the GIS package ARC/INFO. The data for the analysis were derived by transforming the conservation database at Mahidol University (Bangkok) from a tabular database to a spatial format.

Preliminary results of the study include a map depicting the distribution of wildlife habitats and species richness in relation to protected areas, a map of candidate sites for additional protected areas and tables summarizing this information. The most significant finding is that only 13.53% of areas with the highest levels of species-richness are being protected in Northern Thailand.

RÉSUMÉ

Bien que le réseau de zones protégées de la Thaïlande soit important, il n'est pas évident que ce réseau est adéquat puisqu'il n'y a eu aucune évaluation systématique de la distribution en abondance des espèces par rapport aux zones protégées. Par conséquent, les gestionnaires chargés de la planification de la conservation ont de la peine à déterminer des priorités relativement à la conservation. Une analyse des lacunes au niveau de la conservation, qui permet d'évaluer si un réseau de zones protégées est adéquat et qui permet de déterminer les lacunes, constitue une méthode utile d'établissement des priorités.

Au moyen du programme Arc/Info de SIG, une analyse des lacunes, au plan de la conservation, de la Thaïlande du Nord, a été faite. En vue de cette analyse, les données ont été obtenues par transformation de la base de données sur la conservation de l'Université Mahidol, d'un format tabulaire en une représentation spatiale.

Comme résultats préliminaires, on a obtenu une carte qui donne la distribution en abondance des espèces et des habitats de la faune en fonction des zones protégées, des tableaux qui présentent les résultats sous forme de sommaires ainsi qu'une carte des sites à considérer comme d'éventuelles zones protégées. Il a été constaté que les zones protégées de la Thaïlande du Nord ne protègent pas le plus grand nombre possible d'espèces.

1. INTRODUCTION

The goal of this paper is twofold. First, it seeks to illustrate how a Conservation Gap Analysis can be used to assess the adequacy of a protected area system and establish conservation priorities. Second, it demonstrates how a Geographic Information System can be used to carry out such an analysis.

2. CONSERVATION GAP ANALYSIS

Thailand is a biologically diverse nation. It contains 265 species of mammals, 300 reptiles, 900 birds (of which 578 are resident forest species) and 100 amphibians (Arbhabhirama 1988:198-199). Much of this species richness is preserved in Thailand's extensive system of national parks, wildlife sanctuaries and non-hunting areas. Even though these areas comprise just under 10% of the nation, it is not known whether these areas are sustaining as much biodiversity as they could. The adequacy of present conservation efforts is unknown, because there has been no systematic assessment of the distribution of species relative to protected areas. As a result, it is difficult for conservation planners to determine conservation priorities.

Given the diversity of Thailand's wild plants, animals, and ecosystems, as well as the severe constraints on financial resources, manpower, and time, it is even more difficult to identify priorities for conservation. A Conservation Gap Analysis which assesses the adequacy of a protected area system and identifies gaps in it is a useful and relatively inexpensive method for establishing priorities.

The objective of this assessment is to produce a map of the spatial distribution of species, biotic communities or ecosystems in relation to the distribution of protected areas (Scott et al. 1987: 784). This is accomplished by simply overlaying a map of the distribution of protected areas onto a map displaying the distribution of species, biotic communities or ecosystems. With this done one can easily determine the extent to which species, biotic communities or ecosystems are included in the protected area system. In this way gaps in the system are identified, more importantly, however, unprotected areas which can help fill these gaps are also identified. In addition to a map of candidate sites of high conservation values, the output of a Conservation Gap Analysis includes tables of communities which are not represented or under-represented in a given network of reserves. Thus, this procedure assesses the adequacy of protected area systems and reveals conservation priorities in a systematic, quantified way (Burley 1988:229).

Previous Conservation Gap Analyses have produced revealing information on the adequacy of national systems of protected areas. Terbough and Winter (1983) conducted a manual Gap Analysis in Colombia and Ecuador. They sought to identify locations in which the maximum number of endemic bird species could be conserved. By superimposing 156 separate maps of endemic land-bird ranges, they obtained a concentration map showing the spatial overlap of endemic species. This map was subsequently overlaid with a map of existing reserves. It became obvious to the authors (1983: 51) that "virtually none of the crucial areas were contained within the existing or projected park systems of either country."

In Hawaii, a similar analysis was carried out. The ranges of endangered bird species were mapped in relation to existing reserves. Researchers concluded that existing reserves included few areas high in species-richness and even fewer areas rich in endangered species (Scott et al. 1987: 784-5).

In California, Klubnik (1980 [cited in Davis et al. 1990:74-75]) used vegetation types plotted against existing reserves to determine the acreage of each vegetation type in the state and the percentage of each in existing reserves. The result of the analysis indicated that there was an uneven

protection of vegetation in the state: 95% of all alpine habitats were inside reserves but less than 1% of the species-rich riparian habitat was protected.

Such unbalanced protection is not surprising. Historically, the primary reason for establishing parks has been to preserve specific species or special natural phenomena and to encourage recreation (Machlis and Tichnell 1985:19). The preservation of natural biotic diversity was usually only a secondary or incidental consideration (Terbough and Winter 1983:45).

In order to avoid perpetuating this approach and the resulting unevenness in protection, Conservation Gap Analyses should be conducted wherever possible.

It must be recalled, however, that this procedure identifies Environmentally Significant Areas (ESAs) only on the basis of biodiversity. Other resource survey methods such as the ABC method (Bastedo et al. 1984), which use additional factors such as cultural, economic and political constraints, can be accommodated subsequently and used to select areas on the basis of both biophysical and cultural information.

3. DATA SOURCES

The recommendation that Conservation Gap Analyses should be done "wherever possible" amounts to a recognition of the difficulties of obtaining the data required for this type of analysis. Data on habitat and forest extent, let alone the range of species, are still not readily available in many countries. This is a serious impediment to conservation planning. Fortunately, in the case of Thailand, such data do exist and are already in digital form. These data are stored at the Conservation Data Center at Mahidol University in Bangkok.

The Mahidol Conservation Database is a comprehensive collection of information on species distribution in Thailand (including 900 different species). It is currently being used by the Wildlife Conservation Division of the Royal Forest Department, by the Wildlife Fund Thailand, and by many researchers. It is also used by "nature tourists" who want to determine what kinds of animals they may encounter in any park.

The Center uses a system called the MacKinnon-Ali Software System or MASS which was developed in 1984 by John Mackinnon and Rauf Ali for the World Wide Fund for Nature. An updated version of MASS written in Foxbase 2.0 is currently being used.

MASS is described as a "system which provides a ready means of reference to the conservation status of species and habitats at the regional and national levels" (MASS 1990:3). It is used to store and collate data on species and the distribution of their habitat in order to calculate how much of a habitat for a particular species remains and how much of it is protected.

Data on the distribution of species is entered according to two variables, habitat and biounit.

Habitat

Species habitats are identified or coded in terms of two elements, forest type and elevation. Tropical evergreen forest, for example, is divided into 3 classes: TE0, TE1, and TE2.

TE0 = TE forest at plains level up to the foothills (0-200 m)
TE1 = TE forest between the foothills and 600 m
TE2 = TE forest between 600-1,000 m.

There is a similar breakdown for all the major forest types in Thailand.

Biounits

Thailand is divided into 21 biounits. The partitions are based on earlier zoo-geographical divisions.

The MASS database stores information primarily on protected areas, since these are the areas that are well surveyed. Given the need for data on species distributions outside protected areas, it is obvious that the MASS data had to modified or projected somewhat.

This modification was made possible because of the predictive capabilities of the MASS system. The Users Manual (MASS 1990:6) describes the system as capable of predicting which species should occur in an unsurveyed reserve, depending on its geographical location and habitats represented. That is, based on certain variables, MASS can predict where species are most likely to occur. If, for example, a species is known to occur in habitat MD0 (mixed deciduous forest from the plains to 200 m in elevation) in a certain protected area, the system will predict according to different probability levels that the given species will occur in other parks of habitat type MD0 in the same biounit.

Three different levels of probability are associated with this predictive process (MASS 1986:10): possible, probable, and confirmed.

> Species occurrence is said to be possible in a given area, if the area contains suitable habitat and the species is recorded in at least one location within the same biounit.
>
> Species occurrence is said to be probable in a given area, if it has been confirmed in at least 50% of the locations containing the appropriate habitat within the same biounit.
>
> Species occurrence is said to be confirmed in a given area, if its presence in that area has been authenticated by a reliable sighting or other equivalent evidence.

For the purposes of this study, this predictive capability was extended to encompass all habitats in a biounit and not simply those within protected areas. That is, in addition to using the system to predict species ranges in protected areas within a given biounit, it was extended to include all habitats, inside and outside protected areas, in the biounit. For example, if a given species is known to occur in habitat MD0 in biounit NWE, it was assumed that its occurrence was possible in similar (MD0) habitats throughout the biounit, including protected and unprotected areas.

The MASS Users Guide implies that the data can be used in this way: the system, it says (MASS 1990: 3), "stores and collates species and habitat distribution data in order to calculate how much of a habitat for a particular species remains and how much is protected." The use of the words "remains" and the phrase "how much of this is protected" means that habitat outside protected areas, as long as it is in the same biounit, is considered possible habitat. Thus, the modification has not altered the integrity of the data.

The use of the data in this way may be considered similar to types of data obtained from natural history. Species ranges are inferred from data on habitat preference, historical range, and current observed data. Many other researchers have relied on this type on information to carry out similar types of analyses. In their Gap Analysis of Ecuador and Colombia, for example, Terbough and Winter (1983) relied primarily on natural-history information (much of it obtained from museums) for the ranges of the species concerned. Similarly, Harris (1984) used

natural-history information of the individual animal species and not just observed data.

4. CONVERSION TO ARC/INFO

Having obtained information on possible species ranges, it was necessary to extract data from the Mahidol database showing species range broken down by type of species. Then it was required to display that data on a map to show species type distributed by spatial range. To do this, I created a spatial database containing the same elements (i.e., forest type, elevation, and biounit) as those used in the Mahidol database and joined the tabular information to this spatial database.

The Mahidol data were processed first. The Foxbase datafiles on species distribution from the Mahidol database were downloaded to a text file. Each record in this datafile contained information on one species (e.g., name, species number, biounit, habitat, upper altitude, and lower altitude). These files were then imported into dBase III because Foxbase was not available. The records were edited and the records of species which did not occur in the north and other information not required or relevant were discarded. Following this editing, the Mahidol data were ready to be transformed into GIS data.

As mentioned above, to extract the data from the tabular database and append it to the spatial database, the spatial database has to contain the same features (fields) as the tabular database -- i.e. forest extent and type, elevation, and biounits.

First a 1985 forest map (the most recent available) obtained from the Royal Forest Department was digitized.

Elevation data were obtained from the GRID office at the Asian Institute of Technology (AIT). The digital elevation model used was produced by the United States National Geophysical Data Center (NGDC). These data were in raster format. The model was assembled by taking random elevation values and interpolating them to create a grid cell of 5 minutes by 5 minutes. The geographical analysis package, IDRISI, was then used to reclassify the digital elevation model to intervals of 100 m. The model was then imported into ARC/INFO with the Grid-Poly conversion command.

The next step in using ARC/INFO was to overlay the forest-type map on the elevation map. The resulting map was reclassified to conform to the categories used in the Mahidol database. For example, if a polygon had an elevation value between 500 and 600 m and a forest type of mixed deciduous, the class MD0 would be assigned.

Following this reclassification, a map depicting the four biounits which make up northern Thailand was digitized and integrated with the reclassified habitat map. With this accomplished, a spatial database which had the same elements as the Mahidol database was created. The next step was to extract data from the Mahidol database to the newly created spatial database.

To do this, my original plan was to write a program in Info (the database component of ARC/INFO); however, Udai Pradhan of GRID in Bangkok suggested that a program outside ARC/INFO could be developed to the job more easily and quickly. He wrote a program in the programming language C which essentially extracted species from the Mahidol database and attached them to the appropriate polygons in the spatial database.

To summarize the program, it analyzes each polygon in the text file that was dumped from the spatial database and determines its habitat and biounit. Then, it scans the tabular database text file and identifies all the species with an identical habitat and biounit. It also counts the number of different species occurring in each polygon. The result of this search is: a list of species (numbers) occurring in each polygon, the polygon id (a polygon-id is a unique identification number assigned to each polygon by ARC/INFO), and the total number of species occurring in each polygon. This information is then saved to a text file.

This text file was imported into ARC/INFO as an independent datafile. This file was then joined to the spatial database according to polygon id's with the "joinitem" command in ARC/INFO. This same process was done for each of the animal types in the database (mammals, reptiles, amphibians, birds). At this point the database could be searched and the distribution of any wildlife species in Northern Thailand could be obtained.

There were some problems involved with importing the output of the program into ARC/INFO. Some polygons had a long list of numbers of species; for example, for the birds file, some polygons contained 200 different species. This means that 800 characters would be needed to store the information since a species number is 4 characters in length. ARC/INFO, due to limitations in DOS, can import strings of only 128 characters or less. To avoid this problem, the C program created a number of text files to which it saved the results of the analysis. For example, mammals had a maximum of 86 different species in some polygons, to allow for this the program created 6 different files (i.e., mammal1, mammal2, mammal3, etc) with three types of information, polygon id's, species' numbers, and the number of occurrences. For some polygons only the first file was used to store the program's results (i.e. less than 25 (25*5=125) different mammal species occur there); for others two or three were used and, for some, all six files contained species' numbers. These different files were then imported individually into ARC/INFO. They were also joined to the spatial database individually.

A map of the protected area system in Northern Thailand was then digitized and integrated the map derived above. The map of protected areas was required because the goal of a Conservation Gap Analysis is to display the distribution of species richness relative to protected areas.

At this point, the data manipulation and management stage of the gap analysis was complete, and it was simple to do the gap analysis. The database was searched for areas with highest levels of species richness.

5. DATA LIMITATIONS

It is obvious that the results of this analysis are heavily dependent on the data used. Thus, before I go into the analysis of the results, it is important to discuss the limitations of the data used and how that may have influenced the results. Among these are:

(1) the age of the forest type map,

(2) the coarseness of the digital elevation model, and

(3) reliance on estimates of the possible occurrence of species rather than evidence of actual occurrence.

Clearly, the forest extent in northern Thailand is not the same today as it was in 1985. Forest cover in all of Thailand has receded drastically in the last two years, let alone the last six years. Therefore, the associated species

ranges in the spatial database are probably too great. However, the map used was the most recent one available.

The elevation model, which is based on a grid cell of 5 minutes by 5 minutes, is certainly coarse. A more precise one would clearly have been desirable. However, the time required to digitize contour lines at intervals of even 200 meters would have been too great, given the time available for this study. Moreover, considering that the Mahidol database uses intervals of 300 and sometimes 600 m to define habitat boundaries, much of the information from a more precise model would have been lost in the reclassification.

The third limitation is the use of possible rather than actual species range. The MASS Users Guide states (1990:10) that "possible species should be regarded as the maximum possible list and will generally include some species which, while their occurrence is theoretically possible, have only a slight chance of occurring there." The reason is that some areas might be too small to contain a species, or some other essential habitat factor might not be present.

The effect of the first and most serious limitation is to exaggerate the actual extent of forest areas and, because forest type is a component of habitat, the range of species as well. The coarseness of the elevation model probably affects the results to a lesser extent. The elevation data are very generalized, but they are probably not "wrong" in any significant way. Clearly, small areas will not be as readily identifiable while using this model. The effect of using possible rather than confirmed or probable species ranges will again tend to exaggerate the extent of species distribution. All these limitations must be kept in mind when interpreting the results of this study.

Because of the date of the forest-type map, I cannot seriously suggest that the results of this study reflect the adequacy of current protective measures in Northern Thailand. However, the analysis does generally reflect the situation as of 1985 and thus can be used to illustrate the status of the protected area system in Thailand as of that year. In the next section, I will review the results of the analysis.

6. RESULTS AND CONCLUDING REMARKS

The results of this study are summarized in Tables 1 and 2 below. In addition, there are also maps showing the distribution of species richness relative to protected areas.

It is immediately obvious from these data that habitats and areas of species richness are unevenly protected in Northern Thailand. Only 10.31% of the areas with the highest species richness (400+) are within protected areas. If the nine categories of species richness in Table 2 are collapsed into three categories -- low (37.71%), medium (48.76%) and high (13.53%) -- the disproportion becomes even more obvious. Only 13.53% of the areas containing 300 or more different species are protected.

It might be argued that species-rich areas (i.e. areas with more than 300 different species) are adequately protected because they account for only 15% of the area of Northern Thailand. On the other hand, it could also be argued that, if any areas deserve more protection, it is those areas with the highest species-richness. If we conclude that any new protected areas should be as species-rich as possible, then these areas -- the zones of maximum overlap of species ranges -- are strategic sites and merit protection.

However, there are several problems with this approach to conservation planning. First, this analysis takes into account only sheer numbers. It is

unknown (in this analysis, at least) which species are in each area, nor what is their status. Areas with low species-richness may include many endangered, rare, or otherwise special species, and areas with high species-richness may not contain any special species at all. Therefore, in addition to this total-number analysis, the overlap of the distributions of special species should also be carried out. It is possible to do this with the existing database, however, such an analysis has not yet been carried out. Future research will seek to integrate rarity, representivity and other criteria typically used to select protected areas.

Another limitation of this kind of analysis lies in the fact that other types of information are not included. For example, socio-economic and political factors are lacking. But as Terbough and Winter (1983:45) have observed, it is a relatively easy matter to decide where a park should be located; but, because of conflicting cultural, political, or economic considerations, it is quite another matter to translate recommendations into concrete action. Thus, the information obtained from this type of analysis will almost inevitably be only one input into the conservation-planning process.

Despite these problems I believe that conservation planners should not venture too far from recommendations based on the type of analysis illustrated here. As mentioned earlier, biodiversity and species richness seem to be only secondary considerations, whenever it comes to designating protected areas (Terbough and Winter 1983:45; Machlis and Tichnell 1985:19). With the data generated by analyses like the one shown here, it might be possible to balance the scales a little more towards the needs of the wildlife we want to conserve.

The obvious next step is to overlay the results of the analysis on the additional protected areas proposed for Northern Thailand, to see if these proposals will do much to improve the situation. However, details of these new protected areas are not yet available. I hope to obtain this map in the near future.

7. ACKNOWLEDGMENTS

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Biography

Tony Oliveri is a graduate student at the Faculty of Environmental Studies, York University. His areas of interest include protected area planning and management, wildlife conservation, simulation modeling and the use of GIS for conservation planning.

Table 1: Summary of Habitat Types

Habitat Type	Total Area (km2)	Percent of Total	Protect-ed Area (km2)	Percent of Total
HE1	1,066	.8	68	.6
TE0	6,882	5.2	1,481	12.5
TE2	10,793	8.2	1,252	10.6
MD0	12,704	9.7	1,028	8.7
MD2	5,445	4.2	499	4.2
MD3	231	.2	0	0
DD0	22,777	17.4	3,496	29.5
DD2	12,025	9.2	1,706	14.4
DD3	933	.7	25	.2
MPN	67	.1	20	.2
SPN	1,002	.8	138	1.2
SCR	56,868	43.3	2,090	17.6
MSC	401	.3	45	.4
Total	131,194	100.0	11,848	100.0

Table 2: Summary of Species Richness

No. of Species	Total Area (km2)	Percent of Total	Protect-ed Area (km2)	Percent of Total
0-50	1,069	1.44	158	1.62
51-100	2,777	3.74	25	.26
101-150	23,917	32.18	3,496	35.83
151-200	18,625	25.06	3,406	34.90
201-250	13,787	18.55	1,176	12.05
251-300	3,087	4.15	177	1.81
301-350	1,529	2.06	0	.00
351-400	2,442	3.29	314	3.22
400 +	7,095	9.55	1,006	10.31
Total	74,328	100.00	9,758	100.00

COMPARISON OF WEIGHTS OF EVIDENCE AND DECISION-TREE APPROACHES TO MAPPING REGIONAL MINERAL POTENTIAL IN NORTHERN NEW BRUNSWICK.[1]

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ABSTRACT

A multi-layer digital database was created for a study area in northern New Brunswick using a geographic information system (GIS) Seven different types of geoscience data were compiled and digitized: i.) bedrock geology, ii.) mineral occurrences, iii.) regional stream sediment geochemistry, iv.) regional till geochemistry, v.) remote sensing imagery, vi.) lineaments, and vii.) airborne geophysics.

Assessment of regional mineral potential was carried out using two approaches: 1) Weights of evidence (WOE) where coefficients were assigned to each of the input data sets based on the degree of spatial correspondence with the location of known mineral occurrences; and 2) Decision-tree analysis (DTA) where the multi-map attribute data is recursively partitioned into mutually exclusive subsets resulting in predictive, mappable rules which are used in the GIS.

Both approaches produce maps which define portions of the study area with relatively high, moderate and low favourability of containing mineralization. The predictive maps were compared by overlay analysis within the GIS and an integrated favourability map was created.

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1 Work carried out under the Canada-New Brunswick Mineral Development Agreements, 1984-89 and 1991-1995. Project carried by Geological Survey of Canada. Geological Survey of Canada Contribution No: XXXXXX.

COMPARAISON DE LA MÉTHODOLOGIE PAR IMPORTANCE DES INDICES À CELLE PAR ARBRE DE DÉCISION, QUI S'APPLIQUENT À LA CARTOGRAPHIE DU POTENTIEL MINÉRAL RÉGIONAL DU NORD DU NOUVEAU-BRUNSWICK.

RÉSUMÉ

On a créé une base de données numériques multicouche qui correspond à une région d'étude située dans le nord du Nouveau-Brunswick, au moyen d'un système d'information géographique (SIG). Des données géoscientifiques de sept catégories différentes ont été compilées et numérisées : 1- géologie de la roche en place, 2- indices de minéralisation, 3- géochimie des sédiments fluviatiles régionaux, 4- géochimie du till régionale, 5- imagerie obtenue par télédétection, 6- alignements structuraux, et 7- cartographie géophysique aéroportée.

On a évalué le potentiel minéral régional en appliquant deux méthodologies, soit celle de l'importance des indices, où des coefficients sont attribués à chacun des ensembles de données à traiter selon le degré de correspondance spatiale avec l'emplacement d'indices connus de minéralisation, et celle de l'analyse par arbre de décision où des données de cartes multiples qui correspondent à des attributs sont découpées de manière récursive en sous-ensembles mutuellement exclusifs jusqu'à l'obtention d'un ensemble de règles de prévision qui peuvent conduire à la création de cartes utilisées dans un SIG.

Ces deux méthodologies conduisent à la production de cartes qui définissent des parties de la région d'étude en termes de secteurs à probabilité relativement élevée, modérée ou faible de contenir des minéralisations. Les cartes servant aux prévisions ont été comparées à l'analyse par recouvrement dans le SIG, et une carte intégrée de haute probabilité a été créée.

VISUALIZATION OF SPATIOTEMPORAL CORRELATION: A CASE OF TEMPERATURE AND PRECIPITATION

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ABSTRACT

The spatiotemporal analysis function of existing geographic information systems may be improved with the addition of spatiotemporal intersection (STIN) operation. STIN is extended from the intersection operation in 2D GIS overlay model by combining the time dimension and space dimensions. For 3D (x,y,t) STIN operation, a volume rendering technique is required for visualize the spatiotemporal correlation papttern. In this paper, the concept of 3D STIN operation, a conceptual data model and some visualization methods will be discussed. Two data sets, temperature and precipitation, will be used to examine their spatiotemporal correlation.

VISUALISATION D'UNE CORRÉLATION SPATIOTEMPORELLE : EXEMPLE DE CORRÉLATION TEMPÉRATURE-PRÉCIPITATIONS

RÉSUMÉ

Il est possible d'améliorer la fonction d'analyse spatiotemporelle des systèmes d'information géographique grâce à l'addition d'une opération d'intersection spatiotemporelle (STIN). Cette addition est le prolongement d'une opération d'intersection d'un modèle de SIG 2D par calques, qui se fait par combinaison de la dimension temps et des dimensions spatiales. Avec l'opération STIN 3D (x,y,t), il faut une technique de reproduction des volumes afin de visualiser le type de corrélation spatiotemporelle. Dans cet article, la notion d'une opération STIN 3D, un modèle conceptuel ainsi que certaines méthodes de visualisation seront étudiés. Deux ensembles de données, de température et de précipitations, serviront à l'examen de la corrélation spatiotemporelle.

ANALYSIS OF BLACK BEAR HOME RANGE USING A GEOGRAPHIC INFORMATION SYSTEM

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Abstract

Continuous habitat modification is impinging on nature reserves throughout North America, creating insular pockets of wilderness and wildlife. Riding Mountain National Park (RMNP) reflects this development. Consequently, successful management of black bear populations within the area of RMNP requires an understanding of trans-boundary movement and the causes of mortality as well as the cooperation of federal and provincial agencies.

Information derived from radio monitoring 47 black bears of mixed ages, sexes and reproductive status over a three period was analyzed utilizing a geographic information system (GIS). Movements of bears were analyzed on availability and distribution of habitat and unnatural foods at hunter bait sites. Implications and applications of the GIS will be discussed.

LE SYSTÈME D'INFORMATION GÉOGRAPHIQUE ET L'ANALYSE DU DOMAINE VITAL DE L'OUR NOIR

Résumé

Dans toute l'Amérique du Nord, la modification continue des habitats a des répercussions sur les réserves naturelles, confinant la nature et la faune dans de petits espaces isolés. Le parc national du Mont-Riding (PNMR) témoigne de cette tendance. Par conséquent, la gestion efficace des populations d'ours noirs de la région du PNMR exige une connaissance des déplacements transfrontières et des causes de mortalité de même qu'une collaboration entre les organismes fédéraux et provinciaux.

Par l'intermédiare d'une surveillance radio, des informations sur 47 ours d'âge, de sexe et de statut reproductif divers sur une période de trois ans. On a ensuite analysé ces données à l'aide d'un système d'information géographique (SIG). Les déplacements des ours ont été examinés en fonction de la disponibilité et de la distribution des habitats et des points d'appât utilisés par les chasseurs. Les questions soulevées par le SIG de même que les applications que l'on peut en faire seront discutées ultérieurement.

1. INTRODUCTION

Located approximately 225 km N.W. of Winnipeg, Riding Mountain National Park (RMNP) comprises an area of 2,976 km² in the geographic heartland of North America. RMNP overlaps three life zones - grasslands, aspen-oak and mixed wood resulting in a unique and diverse assemblage of plants and animals. The Park has been described as an island of natural environment in a sea of man-altered environment.

In contrast, agricultural land practices, townsites, and recreational developments have drastically modified the peripheral landscape of RMNP. As a result, RMNP has become a protected core, functioning as a wildlife reservoir, surrounded by a narrow, unprotected peripheral zone where bears are baited, hunted and subject to depredation control.

Few species are more in need of an interagency approach to management than is the black bear (Ursus americanus). The Canadian Parks Service (CPS) is mandated to preserve black bears in a naturally regulated system, while Manitoba Natural Resources (MNR) is required to maintain a black bear population to support existing consumptive and non-consumptive uses. Three considerations are significant in achieving this objective: managing licensed hunting, providing opportunities to view bears in natural settings and providing reasonable protection for human lives and property.

In recognition of the need for interjurisdictional management of black bears in the Riding Mountains, the CPS and MNR initiated a cooperative field study in April 1987. This poster paper presents a graphic analysis of bear movements based on availability and distribution of habitat and unnatural foods at hunter bait sites.

2. METHODOLOGY

Field investigations were carried out in RMNP and surrounding provincial areas from May, 1987 - February 1990. Sixty seven different black bears were captured during the study of which 53 bears were subsequently radio-collared and monitored. Instrumented bears were located by aerial telemetry approximately every 4 days from den emergence to den entry. Animals monitored for greater than 6 months which had greater than 10 radio relocations were used to calculate total home range size.

Home range estimates (Dixon and Chapman 1980, Samuel and Garton 1985) were calculated using Program Home Range (Ackerman et al. 1988) developed by the University of Idaho.

Spatial data (point data) generated from Program Home Range were imported into and analyzed using the Intera Tydac SPANS geographic information system (GIS). Home range and core area sizes of bears were determined within the RMNP and the Province. Individual home

ranges were overlain with known bait site locations, activity centers, den locations, and trapsite locations for further analysis.

3. RESULTS

Radio-collared bears were located from the air 3,473 times during the study. The number of radio locations from which annual home ranges were estimated varied from 10 to 198 per bear (mean=53, N=47 bears). The range in radio locations was largely due to bear mortality which occurred during the study.

Home Ranges

Home range sizes were calculated using the 95% harmonic mean for 47 bears (Table 1). The 95% harmonic mean method was chosen as it was the least biased of home range estimators. Outliers were excluded from analysis.

Adult males bears home ranges (X = 464.7 km²) were substantially larger (158%) than the mean home range for adult females (X = 294.8 km²). Seven adult females had 100% of their total home range within RMNP. Two male subadults had their total home range within provincial jurisdiction.

Thirty-nine black bears (83%) had home ranges that overlapped park boundaries. Riding Mountain National Park provided 70.1% of the total home range of adult bears and 60.1% total home range of subadults. Adult females had a substantially larger component of their home range within the park than adult males (female X = 75.2%, male X = 62.3%).

Mean home range size for 10 male subadult bears was 185.8 km². Eight subadult males had 57.5% of their total home range within RMNP (range = 2.03 km² - 719.8 km²). A small sample size prevented a similar comparison for subadult females.

Core Areas

Core areas (Ackerman et al. 1988) are defined as the maximum area where the observed utilization distribution based on harmonic values exceeds a uniform utilization distribution.

Table 1: Estimates of annual home ranges of radio-collared black bears in the Riding Mountains, Manitoba, 1987-1989.

Sex	Age (years)	Sample Size	Mean # of Radio locations	Mean Estimate (km^2)	Range (km^2)
♂	Subadult	10	37.4	185.8	3.5-778.1
♀	Subadult	2	72.5	970.3	860.1 - 1080.4
♂	Adult	14	47.9	464.7	31.4 - 1150.8
♀	Adult	21	62.1	294.8	15.0 - 1143.61

Core areas were determined for 32 adults (males n=12, females n=20) and 9 subadult bears (Table 2). Male adults had substantially larger core areas than adult females (M=156.6 km^2, F=85.9 km^2). Although the mean core areas differed substantially between adult sex classes, the percentage core area within an adult home range were similar (males = 31.5%, females 30.3%).

Table 2: Estimates of annual core area sizes of radio collared black bears, Riding Mountains, Manitoba, 1987-1989.

Sex-Age Class	Sample Size	Core Area Size (km^2)	Range (km^2)	% Core Area within Home Range	% Core Area Park
♂ Adult	12	156.6	4.8-355.1	31.5	70.6
♀ Adult	20	85.9	4.6-305.5	30.3	71.2
♂ Subadult	8	139.4	3.8-334.7	32.5	77.9

Ten adults (7 females and 3 males), and 2 subadults (1 female and 1 male) had total core areas within RMNP. Two males, (1 adult, 1 subadult) had total core areas within the Province.

Home Range Overlap

Home range areas occupied by adults had extensive overlap except for a group of females that lived in the center of the Park. Home range overlap was more pronounced on the southern periphery of the Park (near Pacey Lakes) where the concentration of bait stations was dense.

Core area overlap was also extensive. This was more pronounced in bears that had trans-boundary core areas. Female bears with core areas in the center of the Park were more exclusive of each other as individual core areas overlapped those of only one bear. Male adults had extensive core area overlap. Seven females and 1 male had core areas that did not overlap other radio-collared bears.

Activity Centres

Activity centers based on the harmonic mean of an areal distribution (Dixon and Chapman 1980) were calculated by Program Home Range for all bears and later analysed through GIS. Sixteen of 46 bears (34.8%) had activity centers within .5 km of the RMNP boundary or wholly encompassed within the province. Fifty-four percent of black bears had their activity center within 2.5 km of the RMNP boundary or totally within the Province.

Bait Stations

Sixty-four known bait stations were located within the study area (the study area was delineated by overlaying home ranges of all black bears on the RMNP map). Except for 1 female and 1 male bear, all bears with trans-boundary home ranges had bait stations within their home range (Table 3).

Table 3 Estimates of bait stations locations within home ranges of black bears in the Riding Mountains, 1987-1989.

Sex-Age Class	Sample Size	Mean # of Baits*	Baits Core Area	Baits Home Range
♂ Adult	14	8.9	2.1	7.2
♀ Adult	21	11.3	7.5	4.2
♂ Subadult	10	9.5	4.4	6.4
♀ Subadult	2	18.0	3.0	15.0

* Refers to the mean number of bait locations within the total home range. This includes the area encompassed by the home range and core areas.

The number of bait stations within the home range of an individual bear ranged from a minimum of 1 bait location for all sex-age classes to a maximum of 26 - female subadult, 25 - male subadult, 20 - female adult and 30 - male adult.

Mortality

Twenty mortalities (43%) of radio collared bears for which home ranges were calculated were recorded during the study (13♂, 7♀).

Sixteen bears (80%) were killed by hunters, and 4 (20%) were killed as a result of depredation control. One male adult lost a collar and the fate of 8 bears (5 males and 3 females) is unknown. Eighteen bears were still alive at the end of the study.

4. DISCUSSION AND CONCLUSION

The analysis of black bear home ranges indicates that only one population of bears inhabited the study area. Among study bears there was considerable home range overlap between RMNP and Provincial jurisdictions as nearly all study bears moved across Park boundaries.

Adult male black bears had larger home range (158%) areas and core areas (182%) than female adult bears, however the mean percentage of core areas within an adult bears home range was consistent (males = 31.6%, females 30.3%). Eighty-three percent of study bears had home ranges that overlapped Park boundaries. Male adults had a greater portion of their home ranges within the Province than females (37.4% and 24.8% respectively).

A "core" population of bears (7 adult females) resided entirely within RMNP boundaries. One subadult male had a total home range and core area within the Province.

The practice of baiting bears has raised concerns as bear baiting could significantly influence the regulation and spatial distribution of black bears. In this study I attempted to determine the influence of bait stations on the home ranges of black bears. Except for a resident group of 7 adult females that lived within the Park and two adults (1 male, 1 female) with trans-boundary home ranges, all study bears had bait stations within their home range or core areas. Activity centers of 54% of study bears were within 2.5 km or completely contained within Provincial jurisdictions.

The influence of bait stations is not clearly understood. This study depicted the use of home range and bait stations in a spatial sense. While a large portion of bears were killed at hunter bait stations, most study bears had bait stations within their home range. A temporal analysis of black bear home ranges is required to coincide with changes in plant phenology, weather patterns and seasonal baiting practices to determine the seasonal usage of home range.

The capability of displaying and analyzing home ranges within a GIS has valuable applications within wildlife management. The analysis of an animals home range reveals the ecological requirements of an animal as it includes individual life requisites such as finding sufficient nutrition, shelter and mates. In this example, the RMNP bear population had never before been studied and the impact of bait stations and movements of bears was poorly

understood. The GIS analysis of black bear home range has lead directly to a better understanding and visual assessment of space and habitat required to maintain a population black bears.

5. ACKNOWLEDGEMENTS

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THE USE OF THE CASI SCANNER INTEGRATED INTO A GIS FOR COASTAL ZONE MANAGEMENT

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ABSTRACT

The objective of this study was to assess the utility of the CASI (Compact Airborne Spectrographic Imager) scanner integrated into a GIS for coastal zone management and analysis. CASI is an airborne pushbroom scanner capable of acquiring high resolution visible to near infrared reflected information, making it ideal for collecting marine statistics.

The study area was located along the Cardigan river, on the eastern shore of Prince Edward Island. An image analysis system was used to georeference, enhance and classify the CASI data. Image enhancements were performed to highlight both water colour variations related to sediment load and bathymetry, and also past and present producing aquaculture sites. A supervised classification was performed based on the water colour and exported into the SPANS GIS.

Within the GIS, the classified imagery was integrated with point bathymetry and NTS topographic data. A digital Elevation Model (DEM) was generated from the bathymetry and subsequently used in the production of slope maps for the estuary. Correlation measurements were performed between the water colour classification and the bathymetry, and between the water colour and slope. Using the water colour, bathymetry and slope, a model was developed for suitable aquaculture site selection.

Based on this study, CASI is a feasible tool for coastal zone management. Applications using this data include; water colour mapping, sediment variation and distribution, aquaculture monitoring and site selection.

Utilisation du scanneur CASI intégré dans un SIG et appliqué à la gestion d'une zone côtière

RÉSUMÉ

Cette étude avait pour objectif l'évaluation de l'utilité du scanneur CASI (l'imageur spectrographique aéroporté compact : Compact Airborne Spectrographic Imager), intégré dans un SIG servant à l'analyse et à la gestion d'une zone côtière. Le CASI est un scanneur à barette de détecteurs de haute résolution (3m) capable d'acquérir une composante réfléchie dans la bande allant de l'ultraviolet au presque infrarouge; c'est un instrument idéal pour la cueillette de statistiques marines.

La région à l'étude se trouvait le long de la rivière Cardigan, sur la côte est de l'Île-du-Prince-Édouard. Un système d'analyse d'images a servi à géoréférencer, à améliorer et à classer les données du CASI. L'amélioration des images a été pratiquée afin de mettre en relief les variations de couleur de l'eau en fonction de la charge sédimentaire et de la bathymétrie ainsi que pour mettre en relief les anciennes stations d'aquiculture ou les stations en activité. Une classification dirigée a été effectuée à partir de la couleur de l'eau et elle a été exportée dans le SIG SPANS.

À l'intérieur du SIG, les images classées ont été intégrées avec les données bathymétriques ponctuelles et les données topographiques du système national de référence cartographique Un modèle numérique d'altitude a été produit à partir des données bathymétriques, et il a ensuite servi à la production d'échelles de pente de l'estuaire. Des mesures de corrélation ont été effectuées entre la classification par la couleur et la bathymétrie, ainsi qu'entre la couleur de l'eau et la pente. Au moyen des données sur la couleur de l'eau, sur la bathymétrie et sur la pente, un modèle de sélection de sites aquicoles appropriés a été mis au point.

Cette étude a montré que le CASI est un instrument qui se prête à la gestion des zones côtières. Les applications qui font appel à ces données sont notamment : la cartographie par la couleur de l'eau, la distribution et la variation des sédiments, la surveillance aquicole et la sélection d'emplacements.

INTRODUCTION

The objective of this study was to assess the utilization of CASI imagery for the identification and classification of sedimentation in a shallow water environment, performed within an image analysis system. The classified imagery from the image analysis system was integrated with digital data in the SPANS GIS to determine correlations between the two data sets for coastal zone management and analysis.

The study area incorporates the estuarine environment located along the Cardigan River, Cardigan Bay, Prince Edward Island. The principal study site is located between the town of Cardigan and the mouth of the Cardigan River (527500m E to 538500m E, 5115000m N to 5121500m N; UTM zone 20).

The Cardigan Bay imagery was acquired from the Compact Airborne Spectrographic Imager (CASI), developed by Itres Research Ltd. of Calgary, Alberta. It is one of the most advanced digital imaging scanners available today. The CASI is an airborne pushbroom imager; that is it operates by looking down in a fixed direction and imaging successive lines of the scene under the aircraft, building up a two dimensional image as the aircraft moves forward. The instrument employs a 576 x 288 Charge Coupled Device (CCD) array that is capable of acquiring reflectance information over both terrestrial and hydrological targets in two separate modes: spatial and spectral.

The spatial mode captures reflectance spectra in up to 40 discrete, electromagnetic wavelength intervals (bands) ranging from visible to near infrared (430 - 920nm). Spatial resolution of the data is variable and is generally a function of several parameters including: aircraft altitude, scanner fore-optics, and integration sampling. The spectral mode is used to collect 288 samples (1.8nm resolution) of continuous reflectance spectra in several look directions. The spectral resolution of the CASI scanner ranges from the visible to the near infra red regions of the electromagnetic spectrum and is ideal in the collection of oceanic and estuarine data due to its ability to penetrate water.

The CASI data set supplied by Geomatic Technologies Incorporated was utilized for image analysis. The image data was acquired on the 20 October 1990 commencing at 12:30 ADT, at an altitude of 6000' ASL. The image dimensions were 512 pixels by 2048 lines with a pixel size of 2m x 2.5m. The spectral range consisted of six bands ranging from the ultra violet to the infrared portions of the electromagnetic spectrum. Digital image analysis performed on the CASI data was conducted within the PCI Easi/Pace environment both on a micro computer (DOS) and the RS/6000 workstation (AIX Unix).

IMAGE PROCESSING

Geometric Correction

When image data is recorded by sensors on satellites and aircrafts it may contain errors in geometry such as non systematic or unpredictable distortions. These distortions, found in most

digital imagery include variations in the altitude and attitude (roll, pitch, and yaw) of the sensor platform. Non systematic distortions are unique to each image, and must be measured on each image. These errors are difficult to correct because of their variable nature, although they can be corrected through the use of ground control and tracking data. Measurement techniques to correct the errors involve the collection of ground control points and image registration. The CASI data, acquired through a light weight sensor mounted on a single engine aircraft was subject to the non systematic errors caused by the sensor system attitude such as roll pitch and yaw during the forward movement of the plane.

Most remotely sensed imagery does not directly correspond to any particular map projection; therefore to enable the imagery to be utilized in conjunction with an existing map or imagery from other sensors and dates, the imagery must be geometrically corrected. The intent of geometric correction is to compensate and correct for the distortions introduced at the time of data acquisition so that the corrected image will have geometric integrity. Geometric correction is the process of transforming or registering imagery to remove undesirable or misleading distortions and produce a more faithful representation of the original scene. If left uncorrected, the usefulness of the digital image data would be reduced, and the spatial accuracy of the information collected questionable. Data accuracy is necessary for integration of the data into a GIS.

Georeferencing registers images to a map coordinate system, thus allowing pixel/line coordinates to be addressable in map coordinates. By referencing the image to a coordinate system, the image can be placed in a global context. This step is very important with the trend towards the integration of Image Analysis and Geographic Information Systems.

The initial registration of the data set referenced the image to a user specified coordinate system. This was accomplished through interactive selection of tie-down points from a displayed image and corresponding specified coordinates. The raw CASI image was registered to a Universal Transverse Mercator 1:50 000 NTS mapsheet through ground control point collection and resampling the image. An overall RMS error of less than one pixel was established in the transformation.

Enhancements

Image enhancement procedures are applied to an image data set in order to more effectively display or record the data for subsequent visual interpretation. This is achieved by increasing the apparent distinction between features in the scene. The aim of enhancements is to visually amplify the slight differences in the data set to make them readily observable. Raw image data usually only occupies a small portion of the possible range of pixel values, and imagery displayed in its original state may prevent the distinguishing of similar features. Enhancements are especially important in this specific case study, as the area of concentration, a shallow water estuarine zone, is usually depicted as a homogenous zone in most interpretative situations. The objective of this study is to identify and distinguish several classes within this zone; and the medium for establishing these distinctive classes is through the enhancements.

Radiometric enhancements produce an image that optimizes the full dynamic range of the display

device. This is accomplished through stretching the data across the full range of pixel values (0 to 255) within the display. The raw image data usually does not expand over the full range of values, therefore the contrast stretching function enables the visual detection of small reflectance changes and variations in the data. The stretching function improved the overall contrast of the CASI imagery, although the high correlation between the bands of data lead to redundant information in the processing.

Extensive interband correlation is a problem frequently encountered in the analysis of multispectral image data. That is, images generated by digital data from various wavelength bands often appear similar and convey essentially the same information. Principal component transformation is a technique designed to remove or reduce such redundancy in multispectral data. The purpose of this procedure is to compress all of the information contained in an original n-channel data set into fewer than n 'new channels' or components. The components are then used in lieu of the original data.

Principal component analysis is a linear transform which rotates the axis of image space along lines of maximum variance. The rotation is based on the orthogonal eigenvectors of the covariance matrix generated from a sample of image data from the input channels. A result of the principal component transform is that the new midpoint for each eigenchannel is at 0, with approximately half of the new data being negative and half positive. It is also possible to scale the values in the output eigenchannels to improve the dynamic range. This is very useful on the lower eigenchannels where the dynamic range is small.

The data along the first eigenchannel or principal component has a greater variance or dynamic range than the data plotted against either of the original bands. For channels of multispectral data, the first principal component includes the largest percentage of the total scene variance and succeeding components each contain a decreasing percentage of the scene variance. Furthermore, because successive components are chosen to be orthogonal to all previous ones, the data they contain are uncorrelated.

The results from the principal component analysis were found to highlight even the small variations within the sediment load of the Cardigan River, and were utilized in the classification of the imagery.

Classification

It is possible to analyze remotely sensed data and extract useful thematic information. One of the most frequently used methods of information extraction is multispectral image classification. Classification, in this context, is the process of assigning pixels from a multispectral image to classes on the basis of spectral reflectance characteristics. The overall objective of image classification is to automatically categorize all pixels in image themes. There are two approaches to the classification of an image, supervised and unsupervised.

A full maximum likelihood supervised classification was performed on the image that distinguished the different water classes and estuarine environments. The classes ranged from sand bars and mud flats, through the various levels of sedimentation to clear fresh water. The

land cover was not included in the classification, as not to interfere with the classification of the various estuarine types.

GIS INTEGRATION AND ANALYSIS

Data Integration

A digital database consisting of both point and vector data was established within the ESRI Arc/Info GIS. The database was created from the NTS mapsheet 11 L/2, and the point bathymetric charts provided by the Canadian Hydrographic Survey. Point data was captured from the bathymetric charts consisting of the bathymetric sounding locations found within the Cardigan River. Depth attribute values corresponding to each location were added to the data set independent of Arc/Info, within an ascii text editor. Topographic data was captured from both the NTS mapsheet and the Bathymetric charts and stored in a vector format. The vector data digitized from these two sources consisted of the coastline, roads and rivers. Each of the vector data sets were exported from Arc/Info in an ARCEXPORT format, and imported into the SPANS environment. The point data set was incorporated into the SPANS environment as an ascii text file.

The SPANS environment was used as a tool for integrating the data sets acquired from two independent mediums (PCI and Arc/Info). Within SPANS the data was transformed into a viable and employable form on which an analysis could be performed, modelling functions explored, and the extent of the correlation between the CASI imagery and the bathymetric soundings assessed.

GIS Analysis

The bathymetric point data was manipulated through SPANS functions in order to create products that could be utilized in the assessment of the CASI imagery. The bathymetric points were transformed into a contour DEM map and classified into comprehendible classes. Contouring is a surface interpolation method that is used with ratio or interval point data to generate a surface. An important characteristic of this interpolation method is that the surface is constrained to pass through the data points. The DEM was further manipulated through the slope surface modelling function, and a classified slope map was generated. The classified maps were further utilized within SPANS analysis and modelling functions to determine the extent of the correlation between the bathymetric information and the CASI imagery.

The map analysis functions within SPANS provide a statistical interpretation of the map outputs. A cross tabulation analysis between the CASI imagery and the classified slope and DEM maps were performed to determine the extent of the correlation between the CASI imagery and the bathymetric data. The cross tabulation analysis function produces an area cross tabulation correlation report of two maps. The report contains the area of all overlapping combinations of classes of the two input maps. The result of the cross tabulation indicates the extent of the correlation between the two layers.

The SPANS overlay modelling functions provided a visual interpretation of the extent of the correlation between the CASI imagery and the bathymetric soundings. These procedures enabled the aims of the project to be fulfilled, as the extent of CASI's water penetration capabilities were determined through their correlation with the bathymetric points. The matrix overlay function within SPANS enables logical overlays to be performed on two maps to create a third composite that delineates the relationship between the two map classes. The matrix overlay function was utilized with the CASI imagery and bathymetric data to produce a product that would spatially demonstrate the extent of the correlation between the two data sets. Index overlays follow similar functions and procedures as the matrix overlays, but with a much more extended flexibility. The index overlay function was utilized in the detection of suitable sites for aquacultural activity. The CASI imagery, classified DEM and slope maps were input into an index overlay function with weights and ratings established from the existing aquaculture sites, to create a suitability map for aquaculture site selection.

Through the SPANS capabilities it was determined that there was a high correlation between the CASI imagery and the bathymetry throughout the study area; particularly in the areas of moderate sedimentation and depth. A high correlation was also found between the CASI imagery and slope in the portions of the channel with light to medium sedimentation and a moderate slope.

CONCLUSIONS

The CASI data was determined to be a viable tool in the identification of sediment variations and distributions within a shallow water environment, and when combined with other data sources can be utilized in the exploration of other marine applications.

Due to the digital nature and high resolution of the CASI data, integration of the imagery into a GIS environment was quite facile and useful. Within the GIS system, the accuracy of the image data can be explored in conjunction with a support digital database. Correlations between the two data sets can be determined, and can be used as a basis in a practical application utilizing this data. The application explored within this study was the creation of a suitability map for aquaculture site locations.

Since the bathymetric charts were surveyed in the late 1940's, their current accuracy is questionable, as variations in the attitude of the channel such as its geographical location or sediment load volume will occur over time. This project shows the feasibility of CASI data in the interpretation of estuarine features in a shallow water environment. It renders CASI as a new medium and a viable tool for the charting of shallow water bathymetry within a reasonable time frame and a limited budget.

THE CREATION OF A DIGITAL GEOSCIENCE DATABASE FOR THE PROVINCE OF NOVA SCOTIA

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Abstract

In the fields of geoscience and mineral exploration data integration is critical to effectively analyze the variety of data sets available. The objective of this study was to begin building a geoscience and environmental database for Nova Scotia. The types of data sets included; geophysics consisting of Bouguer Gravity, Total Field Magnetics, and Radiometrics, the 1:250,000 NTS digital topographic base maps, bathometry, mineral locations, stream and lake geochemistry, bedrock geology, fault and fold axes, land use for 1964 and 1986, and the Canadian Land Inventory (CLI) information.

The raster geophysical data consisted of variable resolutions (250m to 2km) thus making the SPANS GIS quadtree data structure ideal for storing and analyzing these data sets. The geophysics were processed and down loaded from a VAX 11/785 and imported into SPANS. The NTS base vector data was separated into three layers; contours, roads and hydrography. Digital Elevation Models (DEM) of 250m resolution were created from the contours in the ARC/INFO GIS and imported into SPANS. The remaining data sets were imported into SPANS directly.

With the data sets fully integrated several queries and modelling processes can be performed. Initially to demonstrate the functionality of the GIS and database, a mineral potential map was derived based on the known mineral locations and their relationship to the geological and geophysical layers. With this map integrated with the land use and land capability information, policy decisions regarding development can be made based on the optimum use of the land. Future information to be integrated include remotely sensed data; Landsat MSS and TM and airborne Synthetic Aperture Radar (SAR).

Création d'une base de données numériques géoscientifiques pour la Nouvelle-Écosse

RÉSUMÉ

Dans le domaine géoscientifique et celui de l'exploration minérale, l'intrégration des données est un facteur critique d'analyse efficace des différents ensembles de données disponibles. L'objectif de cette étude était la réalisation des premières étapes de la création d'une banque de données géoscientifiques de la Nouvelle-Écosse au moyen d'un SIG exploité par micro-ordinateur.

Les différents types d'ensembles de données sont notamment des ensembles de données géophysiques comprenant des données géomagnétiques du champ total, radiométriques et sur les corrections de Bouguer, les données topographiques numériques du SNRC à l'échelle de 1/250 000, l'emplacement de gites, la géologie de la roche en place, l'orientation des failles et des plis, les données sur l'utilisation des terres de 1984 et de 1986 ainsi que les renseignements obtenus grâce à l'Inventaire des terres du Canada.

Les données géophysiques en mode trame étaient à différentes résolutions (250 m à 2 km), ce qui rendait la structure des données en arbre quaternaire du SPANS idéale pour le stockage et la combinaison des ensembles de données. Les renseignements ont été traités et transférés d'un VAX 11/785 à un PC, et importés dans SPANS. Les données vectorielles topographiques du SNRC ont été divisées en trois couches principales : courbes de niveau, routes et hydrographie. Des modèles numériques d'altitude à résolution de 250 m ont été passés avec les données des courbes de niveau dans le SIG ARC/INFO sur un Prime 4050. Le modèle était ensuite transféré au PC et importé dans SPANS. Les ensembles de données restants ont été importés directement dans SPANS.

Une fois intégrées les données géophysiques, géologiques, d'utilisation des terres et de capacité des terres, différentes interrogations et analyses par modélisation peuvent être faites. Voici certaines des applications prévues : modélisation du potentiel minéral à partir de la relation entre des gites minéraux connus et des caractéristiques géophysiques, des prises de décisions politiques fondées sur l'examen du potentiel minéral en fonction de l'utilisation et de la capacité des terres, l'examen des relations entre la topographie et les propriétés géophysiques, le raffinement de la cartographie de la roche en place et le prolongement d'alignements structuraux à partir de caractéristiques géophysiques. Les futures données à intégrer sont notamment les renseignements obtenus par télédétection, soit de S.M.B. de Landsat et de TM ainsi que de radar à synthèse d'ouverture (R.S.O.).

INTRODUCTION

Geographic Information Systems (GIS) have become a valuable tool in the quest for better ways to manage the world's resources. The reasons behind this trend are many, but two of the key reasons include the availability of large spatial data sets, and the ability of GIS to manage them.

Among the variety of sciences that have expressed an interest in GIS are the sciences that explore the earth. The study of geophysics would fall under this umbrella. The purpose of this discipline is to study the physical properties of the earth, and through the evaluation of this information deduce basic characteristics of it. Geophysics is most commonly used to assist in the exploration of mineral resources such as oil and metals. To improve the overall management of our resources the database provides information on the geophysical properties as well as the environmental conditions and capabilities. Now an application of mineral exploration can be carried out and the non-geological factors can be considered when evaluating the exploration targets.

PROJECT OBJECTIVES

It should be kept in mind that the true purpose of this project is to demonstrate the building of a geoscience and environmental database rather than conduct a rigorous investigation of the geophysical properties of the province of Nova Scotia. The three main objectives of this project are;

1) To build a SPANS geoscience/environmental database for the province of Nova Scotia,

2) to demonstrate the use of SPANS geographic information systems in manipulating large data sets,

3) to demonstrate the use of the weights of evidence model as well as to discuss other spatial analysis techniques available in SPANS,

PROBLEM DISCUSSION AND METHODOLOGY

This project can be divided into two major components; the first being the creation of the database, the second being the development of an application for this information.

To be able to understand the problem of the creation of the database one must first have an thorough understanding of the data, as well as the data formats involved. Much of the early stages of this project required the transfer of data from one format to another and from one hardware platform to another. This was because of the wide variety of sources from which the data for this

project was drawn upon.

Working in any field of science is a challenge, but one of the most distressing problems is associated with the ever increasing amounts of data. The problems of data management lies, not only in the quantity of information, but also in the formats in which it is stored. To bring together information from different sources is a problem that is commonly encountered in most GIS projects.

A review of the data sets included in the project are; magnetics, gravity, radiometrics, and elevation. Other information available in this database include mineral occurrences, stream and lake geochemistry, bedrock geology, fault and fold axes, bathometry, land use 1964, 1986, Canadian Land Inventory (CLI) on land capability for agriculture, forestry, angulate and waterfowl habitat.

To be able to build a significant database this project required information from a variety of different sources. The sources that were drawn upon to provide data include; the Geological Survey of Canada, (GSC), the Department of Energy Mines and Resources, Survey Mapping and Remote Sensing Sector, the Nova Scotia Department of Natural Resources, Environment Canada, and the College of Geographic Sciences, (COGS).

GEOPHYSICS

As for the application of mineral exploration, it would be wise to understand the basics of geophysics, and how this information can be used to benefit resource management. The form of the applications will also need to be understood, thus a brief description of the weights of evidence model and basic SPANS analysis techniques will be discussed.

Geophysics is the application of the principles of physics to the study of the earth. It's aim is to deduce the physical properties of the earth based on the physical phenomena associated with it. Structures detectable with geophysics would include; synclines, anticlines, geologic faults, salt domes, ore bodies, clay deposits, oil and water bearing strata. There are a great deal of similarities between the sciences of geology and geophysics, the main difference lies in the type of data that each science uses. The most common forms of data use in geophysics would include radiometric, seismic, gravity, electric, and magnetic.

Radiometric characteristics of the earth are dependant on the radioactive decay of different elements. The data that is to be held in the database would include the three most commonly used elements for radiometrics, namely, uranium, thorium, and potassium. The unstable isotopes of uranium and thorium will decay through a series of states before becoming stable lead isotopes. Potassium, on the other hand will decay in to either calcium, or argon. The level of radioactivity will vary from rock type to rock type and from this the formations below the surface can be better

understood. Certain rock types and formations are typified by certain radiometric characteristics. For example, granites, are typified by high potassium counts, and sedimentary rocks will formally exhibit low counts of radiation. Radiometric data will only provide information about the materials at or near the surface. This is due to the low penetration capability of the gamma waves used in remotely sensing this data. The data was provided in a gridded form at 250m resolution.

Magnetic properties of rocks are partially due to the earth's own field, and partially due to their own permanent magnetism. A rocks permanent magnetism is dependent on the earths magnetic field at the time of solidification. During solidification the molecules will align themselves with the earths field. The rocks will then be subject to the normal crustal movements and will thus be moved, folded and weathered. This will provide a magnetism that is different than that of the earths. The different molecular structure of rocks will exhibit different magnetic properties, thus magnetics can be used to locate a variety of objects. Magnetics can be difficult to interpret because of the ambiguities that can be generated, but in some cases this form of data can be used on its own for detection of specific rock formations. Magnetic data will provide information to a greater depth than radiometrics. The magnetic response of rocks is often related to the amount of iron and magnesium contained within. The data was provided in a gridded form at 812m resolution.

Gravity measurements are concerned with relative measurements rather than absolute measurements. The level of detection required for this type of phenomena is very small. The differences in gravity from one location to another may only be 1/1,000,000 of the total gravitational force. This force is dependant on the latitude and the density of material within the target area, and as such is most commonly used to locate formations that display significant differences in density from one formation to another. The data was provided in a gridded form at 2km resolution.

DATA INTEGRATION AND MANIPULATION

This portion of the project was the most involved. Due to the wide variety of data being imported to this database, along with their different formats, this is where the bulk of the work was done. The following will provide a detailed description of the methods used to handle each different data set.

DEM DATA INTEGRATION

The digital elevation model (DEM) for this database was derived from digital 1:250,000 National Topographic Series map sheets. The DEM, whose grid cell size is 250m encompasses approximately 90% of the province. The map sheets included in the database are 11D, 11E, 11F, 11K, 21A and 21H. The four sheets that were obtained from the department of Energy Mines and Resources, (EMR), arrived on a 9 track magnetic tape with a density of 1600 bpi. The format used to store the files was the Standard

Interchange Format, (SIF). The division of the NTS sheets in ARC/INFO was necessary to provide the 250m cell size, this however, produced small gaps between some of the sheets. If the splitting had been done in a way that overlap would occur then this problem would not have resulted. Correction of this situations was attempted, with reasonable results in SPANS. The mean filter was then used to provide smoothing to these divisions.

GRAVITY AND MAGNETIC DATA INTEGRATION

This data arrived in a VAX backup format from the Geologic Survey of Canada. To transfer it to SPANS a variety of programs and software was utilized. The data transfer included using the programs GSC.FOR or GRAV.FOR, R270.FOR, the Aries image analysis system, and the KERMIT and FTP data transfer conventions.

RADIOMETRIC DATA INTEGRATION

The radiometric data, also from the GSC, came on a 9 track magnetic tape that had a density of 1600 bpi. Since the GSC would have had difficulty sending this information with this density it was initially sent to Intera Kenting where the data was converted.

MINERAL AND GEOCHEMISTRY DATA INTEGRATION

The mineral location data consisted of an ASCII file with latitude, longitude georeferencing and associated attributes for the type of mineralization. The stream and lake geochemistry was also provided as an ASCII file with UTM coordinate georeferencing and associated elements which were analyzed.

GEOLOGY, STRUCTURES AND BATHOMETRY DATA INTEGRATION

These data sets were obtained from the Atlantic Geoscience Centre (GSC) in the form of CARIS GIS ASCII files, the geology and structural data were converted to a DXF format and integrated into the SPANS system. The bathometry was converted to SIF format and integrated.

CLI, LAND USE DATA INTEGRATION

The CLI and land use data were provided in a SPANS quadtree format from Environment Canada, the geographic extent and projection information for the database was also used from this source.

WEIGHTS OF EVIDENCE

The weights of evidence model is used to assess the probability of mineral occurrences for a given area. To be able to use this model an input map of known mineral occurrences as well as other relevant geological maps are required. For this project the modelling could be done using the geophysical information stored in the database.

This model uses a fairly simple process. What is required from this initial step is the creation of a binary map. The first step is to select geologic patterns from the study area. The patterns are selected because they are believed to have some

relevance to the specific mineral occurrences that you are looking for. These patterns can consist of rock types, geophysical or geochemical anomalies, fault or contacts. These features should have some area associated with it. Since many geologic features, such as faults and contacts, are linear in nature they should then be buffered to provide an areal extent. The extent of buffering can vary, and by testing the model the most suitable distance can be determined. The result of this first step is a binary map of the study area depicting areas that are either within the pattern or not. Weights can be assigned to each pattern based on the ratio of area of the pattern and the number of mineral occurrences falling on the pattern.

SPANS GIS is ideally suited to use this particular model, and it has been used on several occasions. The article "Integration of Geological Datasets for Gold Exploration on Nova Scotia" by G.F. Bonham-Carter and F.P. Agterberg uses this model in the SPANS environment for the purpose of identifying locations of possible gold deposits on the south-eastern shore of Nova Scotia.

One of the features of SPANS that allows this model to be used is the modelling language that is built into this GIS package. Through the use of these SPANS equations, along with the proper theoretical and technical experience this model can be run fairly simply while producing quality results.

OTHER MODELLING POTENTIAL

SPANS GIS provides a wide variety of tools at the menu level that allow one to analyze spatial data. Two of the most powerful are the matrix, and index overlay functions. These two are capable of generating valuable information, provided that the person creating the overlay has some experience in the specific application being used. Also available in SPANS are the functions that can produce reports that provide information about the spatial relationships that exist within a database. These reports can help confirm or deny an investigated relationship.

OVERLAY MODELS

Though there are a variety of different overlay functions available in SPANS the two most important are the matrix and index overlays. The matrix overlay allows the combination of two maps to produce a new map based on the users criteria. For this study the Index overlay was used more extensively.

The index overlay is commonly used to determine relative suitability or risk for a specific purpose. For this database it would be primarily used to locate areas that might be locations for certain types of minerals or geologic formations.

This procedure allows the user to overlay up to 14 maps at one

time. It also allows the use of a relative weighting factor. This factor can be used to increase the importance of some elements, while decreasing others. The default weight for each map is an equal amount of the total. The final factor involved in the index overlay is the rating factor. The ratings value is used to assess the relative suitability of a class to the desired application. If a negative value is assigned to a class, then any area of that class will be automatically considered unsuitable.

SPANS REPORTS

There are a variety of different tabular reports that can be produced through the use of SPANS. Among the variety of report functions are the cross tabulation, area, and class means.

The area cross tabulation report will provide data on all of the overlapping combination of classes for the two input maps. This report will provide and indication of the correlation between the two different maps and is commonly used prior to the building of a template for a matrix overlay.

The area report function makes it possible to calculate the total area of any class for a single map.

The class means function will provide a report that calculates the average class value of a map based on the classes of a separate map.

Another report function that is available in SPANS is the ANALYZE / RASTERS procedure. This method of analysis is used to assist in the preparation of suitable classification schemes for a raster image. This function is able to produce a frequency table, a histogram and a correlation and covariance matrices. The correlation matrix will indicate the degree of interrelation between two rasters, while covariance matrix is able to measure the redundancy and quality between separate raster bands.

CONCLUSION

This project successfully demonstrates the creation and application of a geoscience database for the province of Nova Scotia. This database can be used as a tool for mineral exploration, or land use planning, given the data from the Canadian Land Inventory.

It is encouraging that such a wealth of digital information exists if one knows were to look for it. The problem of integration still is a critical issue. In the case of the geophysical data software had to be written to facilitate the integration on that source. In several of the other data sets errors were found and emphasizes the fact that, if it is in digital format does not guarantee the integrity of the information.

It is expected that future work will be done on the information developed for this project. Also, there will likely be expansion done to the data contained within. It is entirely possible that a provincial database with the geophysical data being but one component of the larger database.

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GIS International Boundary Database Pilot Project

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Abstract

The number of international crossings and international border issues are increasing as population centres near the border expand and trade/travel barriers are reduced. The maintenance of the Canada - United Sates 8,891 kilometre land and water boundary is the responsibility of the International Boundary Commission (IBC), a joint agency established under a bilateral treaty. The IBC surveys and maps the boundary line, and regulates all construction within three meters on either side of the line.

Spatial data in analog form and an international boundary database which identifies all the survey monuments, reference markers, and turning points are currently used as management tools.

This paper reports on a pilot project between the Geographic Information Systems Division (GISD) and IBC on the implementation of a GIS International Boundary Database on topographic, boundary, administrative, and cadastral information. It will also review the project needs and requirement study, database design and development, and application development.

LE SIG DE LA COMMISSION DE LA FRONTIÈRE INTERNATIONALE

RÉSUMÉ

Le nombre de passages internationaux et des questions relatives à la frontière augmente au fur et à mesure que les centres habités, situés près de cette dernière, s'agrandissent et que les barrières pour le commerce et les déplacements s'amenuisent. Le maintien de la frontière sur terre et sur l'eau d'une longueur de 8 891 kilomètres entre le Canada et les États-Unis relève de la Commission de la frontière internationale (CFI), organisme mixte créé par une entente bilatérale. La CFI effectue les levés et la cartographie pour la ligne frontière, et contrôle toute construction à moins de trois mètres de chaque côté de cette ligne.

Des données spatiales sous forme analogique et une base de données relatives à la frontière internationale, qui caractérisent tous les monuments, les marques de référence et les stations de nivellement de cette frontière sont actuellement utilisées comme outils de gestion.

Le présent document est un rapport sur un projet pilote entre la Division des systèmes d'information géographique et la CFI au sujet de la mise en oeuvre d'une base de données SIG pour la frontière internationale, contenant de l'information topographique, administrative, cadastrale et celle relative à la frontière. Il examine également les besoins au niveau du projet ainsi que les exigences, la conception et le développement d'une base de données, en établissant des relations entre les objets de la base de données et l'information spatiale relative à la frontière et le développement des applications.

Introduction

The management and maintenance of the Canada - United States is mandated to the International Boundary Commission (IBC). The 8,891 kilometre long land and water boundary requires considerable human and materiel resources to maintain. Maintenance is required for the 8,000 monuments that mark the boundary line and a cleared 6 metre vista, three metres north and south of the boundary.

The resources required for these tasks are diminishing as fiscal restraints take place. The Commission must also deal with growing urbanization along the international boundary as businesses move to border cities in order to lower transportation costs and increase trade with the United States.

This paper documents a cooperative pilot project initiated by the Canadian Section of the IBC, and the Geographic Information Systems Division (GISD), Energy Mines and Resources Canada. The project was to develop a GIS database and application for the management of the Canada - United States international boundary.

The pilot project objectives are;

- to identify possible sources of data for the IBC database;
- to design and implement an IBC attribute database;
- to develop digital data conversion and integration procedures;
- to construct a user interface for spatial and attribute analysis; and
- to investigate the use of orthophoto imagery as a backdrop display for topographic data verification and capture.

Methodology

The GIS IBC database and application were developed and implemented in the GISD, National GIS Technology Centre utilizing Universal Systems Ltd. CARIS GIS software and Ingres relational database management system. The hardware platform, a Sun Sparc2 workstation on the Centre's local area network.

The management issues identified by the Commission specified that the project test site be located along the 49 th parallel boundary line on the Point Roberts peninsula, British Columbia. The test area extended 5 kilometres north and south of the boundary line.

The international border divides the peninsula in half. The Canadian section is situated just south of Vancouver with rapid urbanization. The southern United Sates section has a low population and can only be accessed by water or through Canadian territory.

This site presented the Commission with management issues related to regulatory items. These items are actioned when constructions on the boundary vista have occurred or are planned. Monuments maintained by IBC are present. Frequent requests from IBC clients

regarding cross border smuggling and land management were also considered on choosing this area.

The study is restricted to;
- monument and regulatory information within the test site;
- data and management issues from the IBC U.S. Section were not included in the project terms of reference; and
- monuments refer to boundary monuments, range markers, and turning points.

Users Needs

A users needs study completed by the Commission specified the attribute and spatial queries utilized in daily operations and requests to meet future management issues. IBC clients and data requirements were also identified.

Some of the needs identified in the study are;
- are there any monuments in a user specified area? If so what year were they established and when were they last maintained;
- report and show locations of all regulatory items issued in 1991 that are still open;
- what is the location of the boundary in relation to a specified road; and
- when was maintenance last completed on a monument? What report is the maintenance activity documented in? By whom and what method was maintenance completed?

Data Sets

The National Topographic Series (NTS) 1:50 000 mapsheet for the test area was utilized as the base information. Additional NTS information at 1:25 000 was also incorporated to demonstrate the use of vertical map indexing for interrogation of an area in more detail. The mapsheets were scanned, feature coded, and translated into Standard Interchange Format (SIF) by the Topographic Mapping Division of SMRS Sector.

Geographic coordinates of the test site monuments were made available in ascii files. The ascii files were imported directly into the GIS.

Hardcopy cadastral legal plans from the Municipality of Delta, B.C. were digitized on the GISD's Intera Tydac Tydig package and transferred to the GIS in SIF format.

A 1:5 000 orthophoto of Point Roberts was scanned on the Products and Services Division's Scitex technology and translated into PIP raster file format. The image was transferred into the GISD's PCI Easi/Pace image analysis system and registered to the NTS 1:50 000 base map. The corrected image was saved in PCI's BSQ file format and transferred to the GIS where it was translated into a CARIS raster file format for display and manipulation.

Monument photographs dating back to 1927 were scanned on Geodetic's Division Apple Macintosh scanner and converted into Tagged Interchange File Format (TIFF) utilizing desktop publishing software. The GIS Division's Xerox scanner and Macimage software were not utilized due to TIFF incompatibility with the GIS software. The files were transferred onto the Sun platform utilizing the GISD local area network. The GIS is able to read and display TIFF images and documents as graphic attributes to point, line and polygon features.

Database Design and Implementation

The relational data model was used to design the IBC database. The query and data sets identified in the User's Needs Report served as reference information.

An Entity-Relationship (E-R) model was developed to define the objects or entities used by the Commission to manage and maintain the international boundary and better understand their relationships.

Data normalization was completed to convert the E-R model to one that avoids data anomalies and duplication.

Each entity in the IBC model was identified by a unique code or key. Descriptive information in the database are given the same key value as the CARIS graphic element. The GIS establishes a connection between the graphic key and an object in an Ingres database table through an Attribute Table Definition file.

The physical construction of the IBC database was completed utilizing Ingres's Interactive Structured Query Language (ISQL) and Query By Form interface.

GIS Functions

The pilot project utilizes many of the GIS capabilites available such as spatial and attribute queries, buffering, reporting, and customized menu interface for all GIS analysis and management functions.

Several new analysis and display functions were incorporated into the GIS IBC Database project to demonstrate the feasibility of GIS in terms of the Commission's diverse map and image data holdings.

The GIS functions implemented are described in more detail below as they pertain to the Commissions daily operations.

Vertical Indexing

The Commission used maps from many different scales and projections due to their collaboration with the United States and the long history of surveying and mapping the international boundary.

The GIS system enables the Commission to view and analyze maps of of different scale and projection without changing the parameters of each map, therefore allowing one to quickly interrogate an area in more accurate detail. The term "vertical indexing" describes the function of vertically increasing or decreasing the scale of an area, while indexing or querying the various maps available at each level of scale. Views and queries of the different maps can be performed while the correct georeferencing is maintained regardless of scale or projection.

Multimedia

The maintenance and regulation of the border requires that on site photographs be taken of monuments before and after maintenance, and, obstructions found along the 6 metre vista in order to issue regulatory actions against the obstructor. Monument construction plans, underground cable and or pipelines sketches are also available.

The scanned documents are important in the operating, planning,and budgetary activities that the Commission must carry out. At the same time decreasing the potential of handling damage or loss through digital archiving.

The documents represented as raster images are attached to spatial features supported by the GIS. Monument symbols, parcel lots, and boundary line segments have not only spatial and tabular data but also photographs, plans, documents, deeds describing each item.

Raster Background Display

National Topographic maps serve as important base map information for the Commission to manage and maintain the boundary. The project also investigated the feasibility of incorporating remotely sensed imagery to update, verify, and generate data sets where no digital topographic data is available.

The project took advantage of USL's current development the CARIS Raster Backdrop module which permits the display of raster imagery as background to CARIS vector files. For purposes of this project an orthophoto was scanned, registered, and displayed as background to the topographic base map.

The module permits the user to edit topographic features, improve local registration through interactive geometric correction, and apply image enhancements to the imagery.

User Menu Interface

A menu constructed specifically for the data and analysis functions available to the Commission was developed utilizing Sun's Sunview window environment. The system supports interactive usage by displaying various functions associated to menu icons and buttons.

The desired menu option is executed by keyboard or mouse selection. Menu definitions are stored in ascii files that require no processing prior to menu implementation.

The user interface permits the Commission to set display parameters from a list of available spatial layers. Interactive spatial and attribute queries are supported. Vertical map indexing, multimedia and backdrop imagery display are also supported.

Conclusion

All of the objectives set forth at the initial stages were met successfully at project completion.

Various data sets were converted and integrated, IBC data queries and analysis functions were established, new data sets requiring innovative GIS capabilities were implemented, and a flexible user interface was developed.

The Commissions involvement in the various project activities has established both commitment and the knowledge that GIS technology for the management of the international boundary is both feasible and beneficial to the organization.

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L'UTILISATION DE LA MODÉLISATION MATHÉMATIQUE ET DES SYSTÈMES D'INFORMATION GÉOGRAPHIQUE DANS LA GESTION DU RISQUE DE CONTAMINATION DES EAUX SOUTERRAINES PAR LES PESTICIDES

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RÉSUMÉ

L'environnement est devenu l'une des principales préoccupations des années 90 et un système d'information à référence spatiale constitue un instrument indispensable à sa protection. Cet article présente quelques concepts généraux relatifs à l'utilisation des SIRS dans le domaine environnemental ainsi qu'une application type: la gestion du risque de contamination des eaux souterraines par les pesticides.

Dans le cadre d'un projet de recherche de maîtrise (Gauthier, 1991), Gendron Lefebvre, conjointement avec l'INRS-EAU a mis sur pied une application mettant en valeur la synergie de deux outils: un modèle mathématique pour l'évaluation du risque de contamination (VULPEST, INRS-EAU) et un système d'information géographique (MGE, Modular GIS Environment, INTERGRAPH).

ABSTRACT

The environment will be the major concern on the 90's and geographic information systems are one of the best tools to meet the needs in this field. This paper presents some general concepts for the use of GIS in the environmental field as well as a typical application: risk management of ground water contaminated by pesticides.

Within a research project for a Masters degree (Gauthier, 1991), Gendron Lefebvre, with the collaboration of the INRS-EAU, has developed two typical applications valorising the synergy for the following tools: a mathematical model for the evaluation of risk contamination (VULPEST, INRS-EAU) and a geographic information system (MGE, Modular GIS Environment, INTERGRAPH).

INTRODUCTION

Les pays industrialisés sont aux prises avec des problèmes environnementaux importants en ce qui concerne les milieux agricoles. La spécialisation des cultures et l'accroissement des rendements font en sorte que l'utilisation des engrais chimiques et des pesticides est devenue une nécessité dans l'agriculture moderne.

L'UTILISATION DES EAUX SOUTERRAINES EN MILIEU AGRICOLE

Au Québec, en milieu agricole, l'eau souterraine représente la principale source d'approvisionnement en eau potable. Le secteur agricole de l'économie québécoise compte sur l'eau souterraine pour satisfaire 78% de ses besoins en eau (Hess, 1986). La préservation de la qualité de celle-ci est donc primordiale pour assurer la continuité de son utilisation. Cette préoccupation va en croissant, du fait même de l'apparition de plus en plus fréquente des cas de contamination. La problématique de la protection de la qualité de cette ressource s'inscrit dans la gestion de l'environnement agricole, où les problèmes de la conservation de l'eau et des sols rendent urgente l'implication des divers intervenants (universitaires, privés et gouvernementaux) et les agriculteurs eux-mêmes. La préservation de sa qualité est essentielle pour une productivité économique durable de l'agriculture. Aussi doit-on se préoccuper maintenant non seulement de gérer cette productivité à court terme mais aussi de ses répercussions à long terme.

PROBLÈMES DE CONTAMINATION

On constate très fréquemment la contamination des eaux souterraines par les pesticides utilisés en agriculture. Ce n'est pas nécessairement attribuable à une mauvaise utilisation de ces pesticides de la part des différents usagers, mais principalement au manque d'outils et de solutions pour prévenir ces contaminations. Par exemple, le ministère de l'Environnement du Québec (MENVIQ) a constaté la présence de pesticides dans la nappe souterraine qui alimente en eau potable la population de Sainte-Catherine-de-la-Jacques-Cartier (MENVIQ, 1987). Cette contamination a eu lieu même si les produits homologués avaient été utilisés selon les techniques recommandées par le fabricant et par le ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ).

Les eaux souterraines peuvent contaminer de nombreux cours d'eau car elles assurent la recharge de ceux-ci notamment en période d'étiage. Un rapport de recherche du MENVIQ portant sur la présence de micropolluants organiques dans l'eau potable révèle d'importantes concentrations de pesticides du groupe triazine dans l'eau de consommation de 15 municipalités du Québec où l'activité agricole est majeure. Dans les 15 municipalités, la présence d'atrazine a été détectée dans 75% des cas lors de l'échantillonnage de l'année 87-88 (MENVIQ, 1990). Par ailleurs, les contaminations ne sont souvent constatées que bien après l'application des pesticides et les interventions possibles sont très longues et très coûteuses.

UN MODÈLE D'ÉVALUATION DU RISQUE: VULPEST

Le modèle VULPEST (Villeneuve et al., 1990) est basé sur la simulation mathématique du transport du pesticide dans la zone non-saturée du sol (fig. 1). Le modèle tient compte de la variabilité spatiale des paramètres physiques, hydrodynamiques et physico-chimiques du sol. La modélisation stochastique des processus contrôlant le devenir du pesticide permet d'évaluer la quantité du contaminant susceptible de parvenir à la nappe et ainsi d'altérer la qualité des eaux souterraines. Pour chaque évaluation, le modèle effectue mille simulations stochastiques (en utilisant les distributions statistiques des paramètres). Cela permet une représentation statistique de tous les cas possibles. L'évaluation du risque est établie en relation avec les résultats du modèle et les normes standards de chaque pesticide (concentration maximale permise dans l'eau potable). L'utilisation du modèle permet ainsi de quantifier le risque par des grandeurs physiques mesurables et de manière statistique par des probabilités de dépassement d'un seuil de qualité (norme).

INTÉGRATION DES DONNÉES DESCRIPTIVES ET CARTOGRAPHIQUES

Cependant, pour qu'un tel outil soit utilisable et applicable à l'échelle d'un bassin versant, et efficace aux fins de gestion du territoire, il faut prendre en considération quelques éléments importants.

Premièrement, l'apport d'informations localisées est important dans le processus de simulation du modèle (pédologie, géologie, etc.) et de prise de décision pour la gestion du risque sur un territoire (puits, rivières, etc.). De ce fait, il est important d'établir des liens entre les données descriptives et les données cartographiques. La référence spatiale de l'information par les coordonnées

géographiques permet de localiser les différents paramètres sur le territoire, de les situer les uns par rapport aux autres et de connaître leurs relations spatiales: la proximité (à telle distance de), l'inclusion (dans un rayon de), la contiguïté (voisin de), l'intersection, le recoupement (deux phénomènes qui se superposent).

POLITIQUES DE GESTION EXISTANTES

On dénombre, sur le marché nord américain des pesticides, 500 ingrédients actifs différents et près de 6000 formules commercialisées (Neil et al., 1986). Les multiples ramifications de cette branche de l'industrie chimique ne sont pas sans compliquer la tâche des gouvernements lorsque vient le temps d'effectuer des contrôles sur les produits distribués.

Désireux de réduire au minimum les effets néfastes des pesticides, les différents gouvernements possèdent une législation pour le contrôle des pesticides. Ainsi, la loi québécoise sur les pesticides (loi 72), adoptée en juin 1987 oblige les utilisateurs commerciaux à détenir un permis. Elle a aussi pour objectif d'exercer un contrôle des pesticides sur le territoire. La loi canadienne sur l'usage des produits antiparasitaires adoptée en 1972 a pour but l'homologation des nouveaux produits. Différemment, le ministère de l'Environnement du Québec possède un règlement sur les eaux souterraines mais celui-ci se limite à obliger les foreurs à détenir un permis et à produire un rapport complet sur les conditions hydrogéologiques pour chaque forage. L'analyse de la qualité de l'eau de consommation provenant de puits individuels ne font cependant l'objet d'aucun contrôle régulier ou réglementaire, cette responsabilité incombant aux propriétaires.

Mais ces outils législatifs ne sont pas suffisants pour gérer adéquatement l'utilisation des pesticides et des eaux souterraines. En réalité, chaque milieu physique réagit différemment à l'application d'un pesticide en fonction des conditions hydrogéologiques, de dégradabilité, climatiques, etc. De fait, il faudrait savoir quel pesticide utiliser sur le territoire en considérant à la fois la variabilité spatiale des paramètres conditionnant le mouvement des pesticides dans le sol vers la nappe, l'utilisation du territoire, la localisation des puits et le cadre législatif.

MÉTHODOLOGIE GLOBALE DE GESTION

La protection des eaux souterraines nécessite non seulement des études sur les causes physiques des contaminations et l'évaluation des risques de contamination, mais également le développement d'une méthodologie globale de gestion de l'utilisation des pesticides et des eaux souterraines accessibles aux intervenants dans le domaine de l'eau, de l'environnement et de l'agriculture. Dans un contexte de développement durable, la prévention de ces contaminations potentielles doit être réalisée pour éviter, non seulement les contaminations elles-mêmes avec les risques associés à la santé, mais également les incidences et répercussions dont les dépenses importantes engendrées compromettent l'économie agricole par des coûts de production supérieurs. Une telle prévention doit pouvoir être réalisée avant l'application du contaminant potentiel.

De nombreux pays ont adopté différentes méthodologies d'évaluation et de représentation de la vulnérabilité des eaux souterraines. Parmi les méthodes d'évaluation les plus utilisées, nous distinguons l'expertise, les méthodes à indexation et les modèles de simulation. Parmi ces méthodes, les modèles mathématiques de simulation se présentent comme les seules permettant la quantification des phénomènes physiques. Les modèles mathématiques de simulation du transport des pesticides prennent en compte les processus physiques régissant le transport et la persistance des contaminants. Ils fournissent, avec une précision dépendant bien entendu du modèle lui-même, un résultat ayant une réalité physique définie (concentration, masse, temps) comparable aux mesures réalisées in situ. Les résultats peuvent donc être reproductibles et interprétés sans ambiguïté.

Deuxièmement, les données d'entrées du modèle d'évaluation VULPEST proviennent de sources différentes (Agriculture Canada, MENVIQ, etc.) et leurs formats ne sont pas toujours compatibles. L'échelle et le format peuvent être différents pour chaque document analysé (cartes, données numériques, etc.). Avant d'être utilisées par le modèle, les données devront donc subir un prétraitement d'intégration.

Troisièmement, il faut une méthode de représentation des résultats afin d'exploiter aisément l'information pour une prise de décision concernant l'utilisation d'un pesticide sur un site agricole. Le mode de représentation qui paraît le plus approprié pour traduire et visualiser le risque de contamination est le document cartographique. La cartographie est un outil de compréhension très adapté à la représentation d'information sous forme d'image globale et immédiatement perceptible concernant des phénomènes de toute nature localisables dans l'espace.

L'échelle de travail utilisée pour ce genre d'évaluation est au 1:20 000. Le choix de cette échelle est basé sur la précision des données d'entrée et sur le genre d'analyse recherchée. L'échelle de représentation des résultats variera selon le bassin versant et les phénomènes exposés. C'est précisément l'intégration de ces différents éléments qui fait appel à la géomatique.

LES SYSTÈMES D'INFORMATION GÉOGRAPHIQUE

La géomatique s'appuie sur l'utilisation de l'information et de la haute technologie pour intégrer, suivant une approche systémique moderne, l'ensemble des disciplines qui interviennent dans le processus de production, d'analyse et de gestion des données et de l'information sur le territoire. Les systèmes d'information géographique (SIG) sont des systèmes d'information créés pour aider la gestion du territoire. Le SIG rassemble, organise, gère et traite des données localisées géographiquement et provenant de différentes sources.

Les SIG permettent l'établissement de liens entre les éléments cartographiques (zones pédologiques, homogènes, puits, rivières, etc.) et les bases de données qui renferment des attributs descriptifs (types d'horizon, pente, perméabilité, etc.) ainsi que l'exécution d'analyses spatiales visant à explorer les rapports entre l'emplacement de ces différents attributs (zones à risque, périmètres de protection, etc.). C'est précisément cette capacité d'analyse qui distingue les systèmes d'information géographique conventionnels (cartes, bases de données, etc.) des systèmes d'information géographique (Burrough, 1986).

L'un des avantages des SIG est la considération de la variable temporelle. C'est un atout important pour une utilisation durable et polyvalente de l'information sur le territoire. Cela permet de suivre des phénomènes dans le temps et dans l'espace. Par ailleurs, les SIG garantissent la connectivité de l'information grâce à l'universalité de la référence géographique (Star et Este, 1990. Économiquement, cela permet de réaliser des évaluations à un coût intéressant. De même, les études subséquentes sur un même territoire pour de nouveaux pesticides seront relativement minimes étant donné la pérennité de l'information des SIG. L'utilisation d'un modèle stochastique intégré à un système d'information géographique pour gérer l'utilisation des pesticides en milieu agricole constitue une approche inédite et originale (fig. 2).

Cette intégration permet de visualiser les risques potentiels de contamination et d'identifier les éléments correctifs nécessaires pour la prévention des

contaminations (sélection des pesticides à risques minimaux, périmètres de protection, etc.).

EXEMPLE D'APPLICATION

L'INRS-EAU avec la collaboration du service de Géomatique du groupe Gendron Lefebvre a réalisé une application dans le comté de Richelieu sur le territoire des municipalités de Saint-Robert et de Massueville. Le comté de Richelieu est l'un des territoires qui utilisent le plus massivement les pesticides (Godon et al., 1987). La possibilité de contamination est par conséquent très probable. L'évaluation a été réalisée pour quatre grandes cultures (maïs, blé, avoine, orge) pour cinq herbicides les plus communément employés (atrazine, métolachlore, cyanazine, dicamba et 2, 4-D) sur 99 sites pédologiques différents.

Le système d'information géographique utilisé pour notre application est le Modular GIS Environment d'Intergraph (MGE). Ce système est composé principalement d'un module de gestion du SIG, MGE; d'un module d'analyse spatiale, MGA (MicroStation GIS Analyst) et d'un environnement graphique, MicroStation. L'outil emploie deux systèmes de bases de données différentes. Le modèle VULPEST a été couplé avec DBASE III tandis que MGE utilise ORACLE.

PROTOCOLE D'UNE ÉVALUATION DU RISQUE

La définition du prototype d'évaluation permet d'élaborer chacune des phases à effectuer avec la technologie des systèmes d'information géographique afin de ne pas oublier des éléments importants. Les SIG peuvent exécuter leur plein potentiel si seulement les étapes du projet sont planifiées avec prévoyance. La moindre erreur qui peut sembler mineure risque d'avoir des répercussions en chaîne sur l'ensemble des données conçues comme un tout homogène. Cela peut compromettre les prévisions établies, les délais et les coûts de réalisation.

Le processus de production d'une évaluation du risque de contamination sur le territoire comprend quatre étapes: 1) l'acquisition des données, 2) le prétraitement, 3) la manipulation, 4) la représentation des résultats (fig. 3).

L'acquisition des données est une étape très importante. C'est celle-ci qui déterminera le temps de réalisation et la complexité des différentes manipulations du projet. Il faut bien identifier les organismes qui possèdent l'information

pertinente afin de ne pas multiplier inutilement des échantillonnages ou d'autres traitements servant à obtenir l'information.

Le prétraitement permet de réaliser et de structurer l'intégration des données dans le SIG et les tables de données. MGE articule son information graphique à une structure de données vectorielles, où l'emplacement de chaque point cartographié est décrit par une paire de coordonnées. Les lignes sont représentées par une série de points reliés les uns aux autres et les surfaces, par plusieurs lignes qui se recoupent de manière à délimiter un espace (polygone homogène). Les positions sont très exactes dans ce système et s'harmonisent d'ailleurs aux principes de représentation cartographique classique (Star et Este, 1990). Cette étape constitue le coeur même du système et il est important que tous les éléments graphiques et non-graphiques soient parfaitement au point pour réaliser un "graphique intelligent" afin de pouvoir entreprendre des analyses spatiales.

L'étape "traitement et analyse" est un processus permettant de faire ressortir des informations nouvelles à partir d'analyses statistiques et spatiales des données existantes. C'est à cette étape que l'on fait appel aux données pédologiques, géologiques et climatiques afin de circonscrire des zones homogènes nécessaires aux simulations. Par la suite, les simulations du modèle VULPEST permettent d'obtenir les concentrations de pesticide arrivant à la nappe et les probabilités de dépassement de la norme pour chaque site homogène discrétisé.

VISUALISER LE RISQUE DE CONTAMINATION

Les premiers résultats prennent la forme d'une carte des probabilités de risques de contamination. Cette carte est réalisée par une première analyse spatiale ayant comme but la discrétisation des zones homogènes dans lesquelles seront réalisées les simulations. Cette analyse est effectuée par superposition au niveau des paramètres hétérogènes du territoire (pédologiques, géologiques et climatiques). Par la suite, le SIG envoie les paramètres de chaque polygone homogène au modèle VULPEST pour simulation. Puis, les résultats du modèle (concentration arrivant à la nappe) sont retournés au SIG pour être traités statistiquement (figure 3). Ce premier type de carte est établi en sept classes de probabilité de risques. La classification des probabilités est la meilleure façon de représenter le degré réel d'exposition à une contamination (neil et al., 1986). Enfin, le SIG attribue par analyse, les probabilités de risques de contamination à chque polygone homogène ayant servi à la simulation (carte 1).

Les probabilités de risque acceptable dans l'utilisation des pesticides ne sont pas les mêmes que les autres contaminants. Pour un grand nombre de contaminants, les probabilités pour un risque acceptable sont évaluées à 1 cas sur 1 million. Tandis que pour les pesticides, les probabilités sont établies en fonction des effets bénéfiques et négatifs (Casarett et Doull's, 1986). Donc un risque nul est invraisemblable pour l'utilisation des pesticides (Tardiff et Rodricks, 1987). La pondération des effets bénéfiques et négatifs établit un risque volontaire de 1 cas sur mille pour l'utilisation des pesticides (Rodricks et al., 1987; Whipple, 1987; Neil et al., 1986). Par conséquent, la première classe établit un niveau d'exposition acceptable, ce qui représente une probabilité inférieure ou égale à 0,1%. Les autres classes établissent un risque relatif qui permet seulement de comparer le potentiel de contamination des pesticides sur différents sites.

SCHÉMA DE GESTION DES PESTICIDES

Une analyse spatiale plus complète permet de réaliser un deuxième type de résultats pouvant servir comme schéma d'utilisation et de gestion des pesticides (carte 2). Celles-ci montrent quel pesticide comporte le moins de risque pour chaque site évalué pour une même culture et les périmètres de protection pour les puits, les rivières, les ruisseaux et les fossés de drainage. Ce type de carte est obtenu en réalisant une analyse spatiale des cartes de probabilité de risques pour les pesticides évalués pour une même culture. Enfin, il y a une analyse spatiale pour déterminer les périmètres de protection des milieux sensibles. Actuellement, les périmètres de protection sont déterminés avec des paramètres fixes. Éventuellement, ceux-ci seraient déterminés avec un modèle simulant le mouvement horizontal des pesticides dans la zone saturée du sol.

CONCLUSION

Comparativement à d'autres méthodes et approches, un tel outil permet d'évaluer et de visualiser les risques de contamination des eaux souterraines par les pesticides et de gérer toutes les connaissances nécessaires pour prendre une décision sur des critères objectifs et justifiables du point de vue scientifique.

La puissance et l'originalité de cet outil tiennent du fait de l'intégration d'un modèle d'évaluation (VULPEST) et d'un système d'information géographique (MGE). Le modèle VULPEST permet d'évaluer rapidement le risque de contamination à partir de simulations stochastiques avec les paramètres influençant le transport et la dégradation des pesticides dans la zone non-saturée du sol et les

normes toxicologiques. Le système d'information géographique (MGE) permet d'exploiter les données nécessaires pour une évaluation précise du risque de contamination sur le territoire. Il permet d'analyser les résultats en relation avec d'autres composantes de l'environnement. Enfin, la mise à jour de l'information est simple et rapide.

La souplesse et la qualité de cet outil permettent l'utilisation rationnelle de la visualisation à l'écran pour réaliser une évaluation complète et rapide du territoire. L'évaluation de plusieurs pesticides sur un territoire à partir d'une méthode traditionnelle comporterait un nombre exorbitant de cartes. L'analyse et la prise de décision seraient ainsi longues et fastidieuses. De plus, la recherche d'une information précise sur un site, nécessiterait de longues périodes de recherche dans les bases de données. Par la structure des systèmes d'information géographique, il est possible de visualiser à l'écran l'information désirée pour un objet sélectionné ou pour une application précise.

L'utilisation de ces cartes permet donc d'identifier les éléments correctifs nécessaires pour la prévention des contaminations des eaux souterraines par les pesticides. Ces résultats peuvent être utilisés pour une planification d'aménagement, pour une présélection de sites ou même pour localiser l'implantation d'un puit en un lieu à risque minimal.

On peut tester également de façon préventive le potentiel de contamination d'un nouveau produit (première utilisation dans une région ou nouvellement sur le marché). Avec un tel outil de décision, les responsables pourront souscrire des indications relatives à l'utilisation des pesticides, ou pour l'homologation des nouveaux produits.

On pourra enfin sélectionner les zones agricoles critiques où les efforts d'intervention devraient être renforcés (échantillonnage, établissement d'un réseau de surveillance, prévention, conservation, etc.) pour permettre une meilleure gestion des ressources.

Pour rendre un tel outil encore plus performant, certains développements pourraient être envisagés. Par exemple, on pourrait coupler un modèle de transport dans la zone saturée du sol qui permettrait de prédire la quantité de pesticide parvenant à d'autres systèmes (rivières, lacs). Ceci pourrait permettre la détermination scientifique du dimensionnement d'un périmètre de protection pour un puit et une rivière. Par ailleurs, l'application des systèmes experts pourrait automatiser le processus de cartographie et permettrait d'interpréter les résultats et d'aider la prise de décision.

L'exemple réalisé dans le comté de Richelieu a démontré l'utilité de cet outil. En effet, la visualisation des risques de contamination pour les pesticides testés a permis de distinguer les pesticides comportant le moins de risque de contamination pour chaque site sous différentes cultures. Les réactions des utilisateurs potentiels interrogés sur les essais cartographiques ont permis d'apprécier l'utilité pratique de ces cartes. À divers niveaux, le rôle de la cartographie est important. Elle permet de guider les décisions des planificateurs ou des experts dans le choix des pesticides selon les caractéristiques du milieu. Dans le domaine de la conservation et de la protection des eaux souterraines, elle peut aider les législateurs à prendre ou à renforcer les mesures de contrôle ou la formulation d'avis pour l'homologation des pesticides. Enfin, il est certain que dans le cadre de la préoccupation actuelle de la conservation de l'environnement, ces cartes appelées à une fonction très utile, notamment en manière de protection des captages d'eau d'alimentation et des zones naturelles sensibles.

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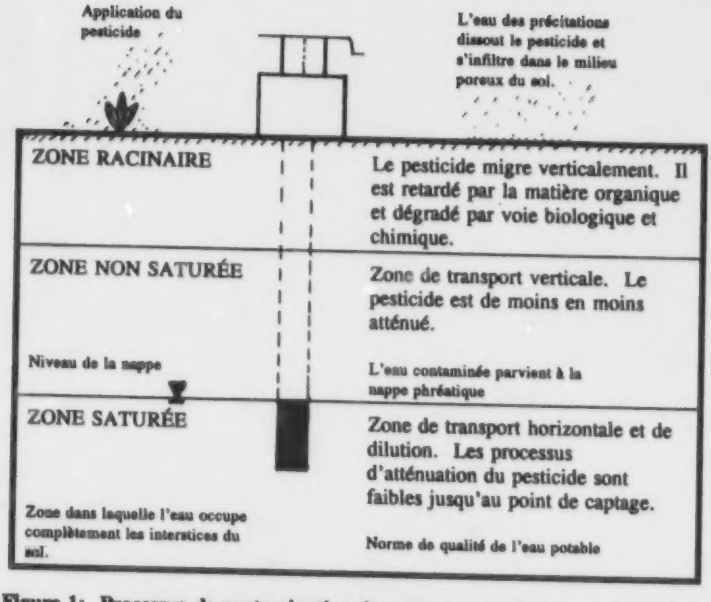

Figure 1: Processus de contamination des eaux souterraines par un pesticide

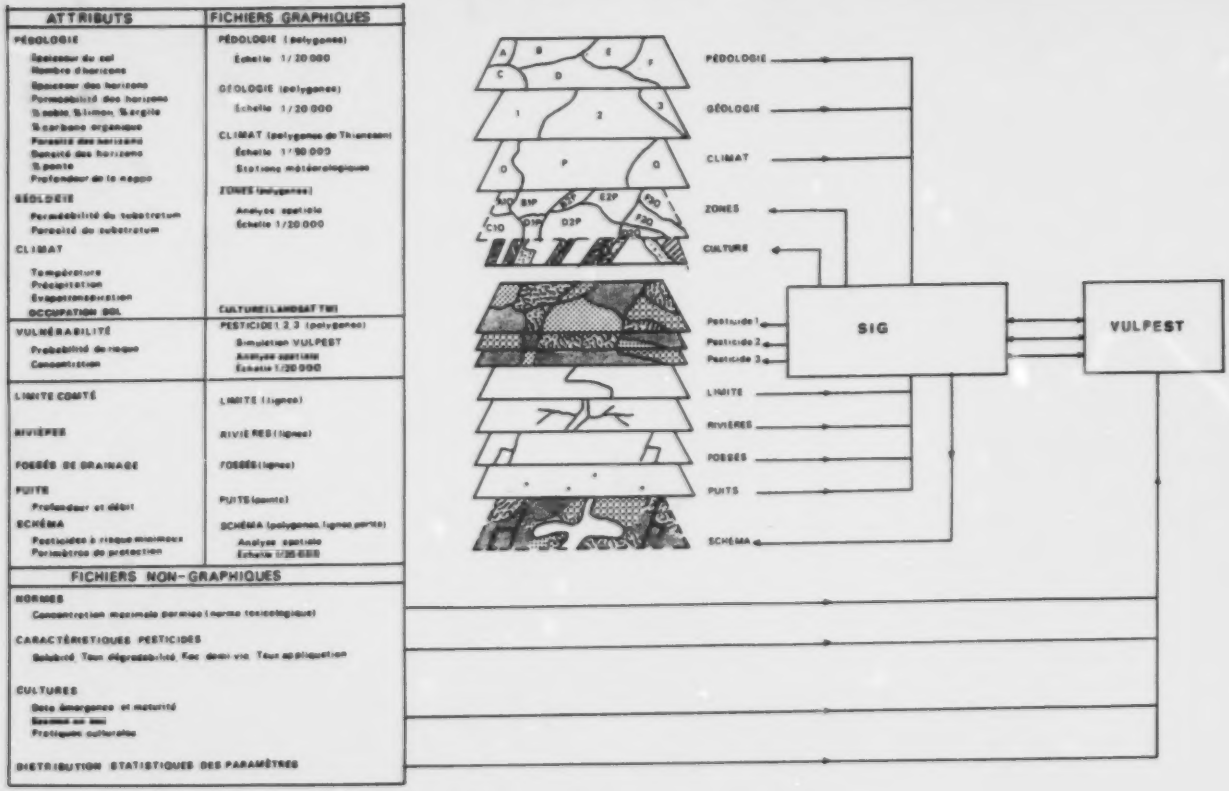

Figure 2. Schéma du SIG intégré à VULPEST (Gauthier, 1991)

ÉTAPES	DESCRIPTION			
ACQUISITION DES DONNÉES	IDENTIFICATION DES DONNÉES POUR L'ÉVALUATION . Caractéristiques du sol . Caractéristiques du climat . Caractéristiques des cultures . Caractéristiques des pesticides	IDENTIFICATION DES SOURCES DISPONIBLES . Fédérales . Provinciales . Municipales . Privées	FORMAT DES DONNÉES . Base de données . Fichiers numériques . Etc.	VÉRIFICATION DE LA QUALITÉ DE L'INFORMATION . Critères de qualité
PRÉTRAITEMENT	ORGANISATION DE LA STRUCTURE DES DONNÉES . Structure des tables de données . Conversions de formats . Préparation des données pour l'intégration au système	ORGANISATION DE LA STRUCTURE DU SIG . Définition des éléments du système . éléments graphiques et non graphiques attributs . Définir les relations entre les objectifs et les attributs	ENTRÉE DES DONNÉES . Numérisation . Interface entre les données existantes	VÉRIFICATION, CORRECTION ET MANIPULATION . Vérifier le contenu des tables de données . Vérifier la fermeture des polygones . Génération des nœuds . Nettoyage des lignes . Fleuve contrôlés . Liens topologiques
TRAITEMENT ET ANALYSE	ANALYSE SPATIALE . Détermination des zones d'investigation par superposition des données pédologiques géologiques et climatiques homogènes	SIMULATION VULPEST . 1000 simulations par zone homogène des concentrations temporaires annuelles . Probabilité de contamination	TRAITEMENT DES RÉSULTATS . Classification de risque . Interprétations	ANALYSE SPATIALE . Assignation à chaque polygone homogène . Périmètres de protection . Comparaison des pesticides
PRODUCTION ET PRISE DE DÉCISION	PRODUCTION . Cartes . Fichiers . Visualisation à l'écran	PRISE DE DÉCISION . Zones à risque . Zones de protection . Recommandation de pesticide la moins dommageable . Réseau de surveillance . Hiérarchisation		

Figure 3: Schéma de réalisation d'une évaluation

Infrastructure Management Using GIS

A Cooperative Pilot Project between RMOC and EMR

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Abstract

The paper describes a system which was recently developed and implemented at RMOC for the maintenance and rehabilitation planning of regional roads with a geographic information system. The GIS will be used to generate various scenarios of rehabilitation and capital works for presentation to RMOC's Budget Review Committee. The paper discusses the methodology used in executing the pilot project with special emphasis on the integration of various sets of spatial information such as SMRSS 1:50,000 and RMOC 1:25,000 digital data as well as attribute information dealing with road inventories and conditions, economic analyses, official plans, and public transit.

Un SIG pour la gestion des infrastructures

Résumé

L'article décrit un système de planification de l'entretien et de la restauration du réseau routier à l'aide d'un SIG. Ce système a récemment été mis en place à la MROC. Le SIG sera utilisé pour générer divers scénarios d'entretien, de construction, et de restauration en vue de présentation au Comité d'étude du budget. L'article met l'emphase sur la méthodologie employée pour l'exécution du projet. Une attention particulière est portée à l'intégration de jeux de données spatiales 1:50,000 du SLCT et 1:25,000 de la MROC ainsi que des bases de données d'attributs comprenant l'inventaire des routes ainsi que de leurs conditions, les résultats d'analyses économiques, le plan directeur et les analyses de la circulation du transport public.

ACRONYMS

APWA:	American Public Works Association
EMR:	Energy, Mines and Resources Canada
ESD:	Environmental Services Department, RMOC
GISD:	Geographic Information Systems Division, EMR
GRIS:	Geographically Referenced Information Systems, RMOC
MEA:	Municipal Engineers Association
MTO:	Ministry of Transportation, Ontario
OGRA:	Ontario Good Roads Association
PL:	Planning Department, RMOC
RIMS:	Roadway Inventory and Management System
RMOC:	Regional Municipality of Ottawa-Carleton
SMRSS:	Surveys, Mapping, and Remote Sensing Sector, EMR
TD:	Transportation Department, RMOC

1.0 Introduction

The GIS Division of EMR promotes the use of SMRS data in GIS applications through setting up innovative pilot projects with various agencies. Under these premises, cooperation was established between RMOC and the GISD to execute a pilot application to assist in planning the rehabilitation of regional roads.

The project is broken down into three phases, with each phase becoming increasingly complex, and evolving from automated cartography to spatial analysis and information management. These phases are described in greater detail in section 2.0.

1.1 EMR's Objectives

EMR produces digital topographic data at scales of 1:50,000 and 1:250,000, and wishes to promote the use of this data in GIS applications. This pilot project makes use of the street centerlines, elevation contours, public buildings, and other data found in the 1:50,000 databases. It is predicted that other municipalities and provincial departments will show an interest in this data for their own GIS applications, since the RIMS application is common to municipalities across Ontario, and across Canada in varying formats.

Another objective is to demonstrate how EMR data can be integrated with other spatial data from other sources, since GIS applications are rarely built on one single source of data.

It is equally important for the GIS Division to complete a real application in a timely manner to market our data before potential clients embark on spatial data collection efforts.

1.2 RMOC's Objectives

RMOC has corporately implemented a geographic information system. Since then, GRIS has conducted user needs sessions with each department (ESD, TD, PL) and has set-up a database schema to accommodate future application needs. These sessions have left the end users with high expectancies. To keep the momentum going without sacrificing planning for the long term, it was decided to set-up a pilot project in a high visibility area - roadway rehabilitation (RIMS)[1] and capital projects scenarios. These applications are not only highly visible, they also recur on a yearly basis and require input and data sharing from various divisions within the TD, ESD, PL, and the Finance Department.

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1. RIMS: Roadway Inventory Management System. It is a PC-based database software package which stores and processes municipal roads inventory and appraisal data. The package was sponsored by the Tri-Committee.

2.0 Methodology

2.1 Team Organization

The project team consisted of three concentric levels (Figure 1). The core group, composed of three members from GRIS, TD, and GISD, is responsible for the project planning, execution, and documentation. The second level members have been running RIMS on a yearly basis and now provide the core with valuable guidance as to how the roads inventory and appraisal data is collected, processed, and disseminated to decision-makers within the TD. The Planning Department assists in guidelines for integrating land use and official plans as other layers of spatial data. Decision-makers from the TD make up the third level. This level plays the role of a review committee at the end of each phase when the core group makes formal presentations. These reviews provide the core group with feedback before it embarks on the next phase. There is, however, a seond objective to these presentations - that is to educate the end users on the intricacies of GIS via data and functions that they are familiar with. The core team is also trying to spur the flow of creative juices from these decisison-makers as fuel for the next pahses of the pilot project.

Although the above arrangement may appear to be a bottom-up approach, that is not the case. It should be remembered that this pilot project is being executed within the much broader scope of corporate GIS implementation, where RIMS had been identified as a high priority application. Another interesting characteristic of this project is that intimate knowledge of both RIMS and of the GIS are found within the core group.

2.2 Phase I: RIMS - From Automated System to GIS

In RIMS, each table has a common field which holds the unique street segment number. This segmentation reflects the manner in which the data was collected in the field (i.e. from intersection to intersection). Hence, before porting any RIMS attribute data to the GIS, the project team structured the spatial data to conform to this segmentation. The RIMS dBase files were then translated to the empty Oracle tables previously created within the GIS. Upon completion of these few steps, the team now had a basic GIS consisting primarily of street centerlines and associated attribute data.

2.2.1 Conditional Symbology

One of the first tasks required from this basic GIS is to display the overall status of the regional road network. The condition rating - one of the attributes in RIMS - is an overall index of the segment's condition, based on its surface and shoulder conditions, its structural adequacy, its level of service, and its drainage and maintenance needs. For example, a segment in perfect condition has a rating of 100, while a poor one will rate less than 50.

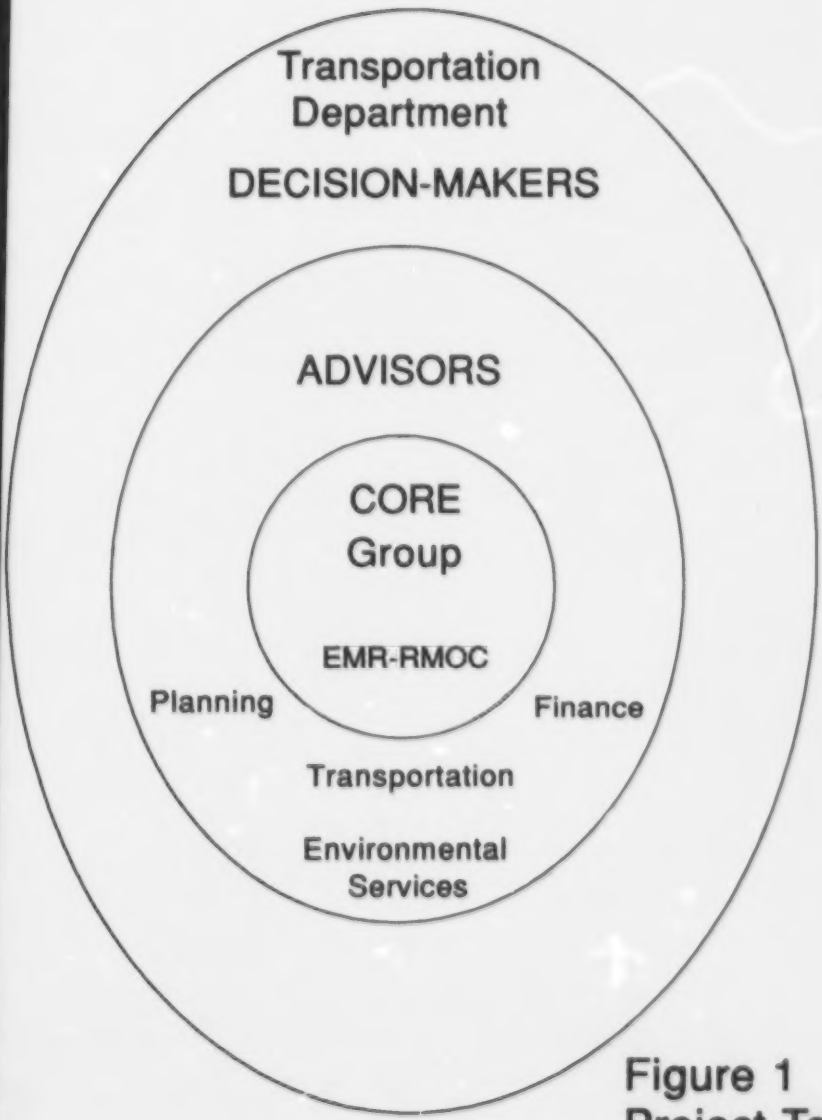

Figure 1
Project Team
Organization

Through a conditional symbology macro, the team assigned colours to the ranges of condition rating, i.e. black for 100, green for 70 to 99, etc. The GIS, through this macro, verifies the value of the condition rating field before displaying the segment on the screen, thus providing a thematic map of the road network's condition. There are 127 fields in RIMS attribute tables - any one of these fields (or combination of fields) could have been accessed through conditional symbology to produce customized thematic maps.

2.2.2 Reports

The next step is to re-create the reports previously obtained through RIMS. Only this time, the text reports and the matching maps are created simultaneously. The following partial list of queries indicates how RIMS data is widely used by the various Divisions in the Transportation Department:

i) All segments now exempted from restricted loading due to improved structural adequacy.

ii) Historical reports of new and reconstructed roads on a yearly basis.

iii) All segments in semi-urban or rural environments with a level of service less than 11 (LOS D or worse).

iv) All segments which should be improved immediately.

v) All segments with a structural adequacy less than 13, but greater than 7 (implying that structural improvements will be required in the next 1-5 years).

vi) All urban and semi-urban segments slated for major improvements, such as new base and surface, reconstruction with or without storm sewers, or resurfacing and widening.

vii) All segments which require improvements in the next 5 years, broken down into types of improvements, with subtotals for lengths and costs.

viii) As in vii) above, but where time of improvement is "NOW".

ix) All segments where improvements were performed in the previous year.

x) Total accomplishments per year, by type of improvement.

xi) Total road length by roadside environment (urban, semi-urban, rural) by municipality and total lengths by surface type.

xii) Total length by road classification for each municipality.

Before any of the above queries are processed, all street centerlines are displayed as black segments. Upon execution, only those street segments which meet the query criteria stated in the query are redisplayed in a contrasting colour. A tabular listing of these street segment names, numbers, and relevant attributes is also produced. Both of these outputs are available in hardcopy.

2.3 Phase II: Ad Hoc Query Development

2.3.1 Links to Other Data

In the past, the various decision-makers in the Transportation Department would study the tabular reports produced by RIMS in conjunction with information produced by other agencies before finalizing rehabilitation plans. With the inherent flexibility of the GIS, additional tables can be designed to hold data produced by these other agencies to enable broader queries. Results from economic analyses and bus delay statistics can now be associated to individual road segments.

For example, bus delay statistics include data on the street segments affected, the bus route number, the time delay per bus, the volume of buses during am and pm peak hours, and the total delay time. The economic analysis results are in the form of ratios also associated to road segments.

The link between the spatial data and these new attributes is also the street segment number. With this link established, queries can now include criteria involving RIMS, bus delays, and/or economic cost/benefit ratios. For example:

i) Select all roads requiring widening and where bus delays exceed 2 hours per day;

ii) Select all roads requiring immediate reconstruction and whose cost/benefit are less than 0.5;

iii) Select all roads where bus delays exceed 2 hours per day and that should be improved next summer, and sum up the estimated costs of these improvements.

2.3.2 Spatial Relationships

Up to this stage, the GIS was chiefly used to present query results in a graphic form. In this phase of the project, the project team demonstrated the use of spatial relationships between roads and their surrounding environment by taking advantage of non-roadway features found in the spatial datasets, of the data supplied by the other Departments, and of the more advanced tools within the GIS.

In the first instance, features such as schools, hospitals, and other public buildings are useful in timing specific projects. Buffers can be set-up around schools to identify roads

requiring reconstruction "NOW" which pass through these buffers, to limit heavy construction to the summer holidays.

Secondly, the layers containing the municipalities' work plans, the Planning Department's site development plans, and ESD's capital works programs are also activated to track the projects which impact on road rehabilitation planning.

Thirdly, the network analysis tools supplied with the GIS are used to determine temporary detours where construction impedes traffic flow. Network analysis may be relatively straightforward but could also involve the development of macros (section 3.3).

The attribute tables pertaining to the features introduced in this phase were kept relatively simple and contain information about:

- Year of projected work;
- Duration of projected work;
- Status of work (pending approval, in progress...);
- Type of work (storm sewer, sanitary sewer, watermain, road repair, residential subdivision, commercial/industrial development,...); and
- Jurisdiction.

The team demonstrated sample analyses involving RIMS data and the above features to the potential users of the GIS. This initiated valuable brain-storming sessions with the end-users to prepare sequences of queries required to a preliminary rehabilitation scenario.

2.4 Phase III: Macro Development and Scenario Generation

Through the evolution of phases I and II, the Transportation Department was exposed to the evolution and the potential of GIS, as well as to the work involved in designing the database and the queries. Phase III will determine which queries and analyses will be required on a regular basis, to form part of a standard basic analysis.

These specific queries can then be set-up, tested, and stored as macros to be later recalled at the click of a mouse, via the interface of a customized menu. These macros can be enhanced to perform tasks other than database queries, such as:

- zooming-in to a specific geographic area of RMOC;
- making certain layers of information visible (or invisible) in preparation for the query;

- prompting the user for responses which determine how the macro performs its instructions;

- calling the next macro in the chain of queries.

Where sophisticated network analysis is required, macros will play an important role in accessing the attribute tables to supplement the basic networking tools. The two following cases emphasize this need:

i) Where construction detours are concerned, the selection of an alternate route not only depends on the spatial sequence of the road segments, but also on their number of lanes, speed limits, vehicular and structural capacities, and on their ownership.

ii) Where lists of "continuation" projects are established, the selection of segments lying between two improved sections requires locating two-lane segments between three-lane ones, or two resurfaced sections on each side of a gravel section, etc...

These enhancements allow for the development of automated GIS applications that can be invoked by the transportation analysts. This will not prevent end users to query the database on an ad hoc basis, which is especially useful when performing project and/or area specific analyses "on the fly". These users will become familiar with GQL and with the datasets which form the various building blocks of the system.

3.0 Expected Results and Benefits

At the time of writing, the project team is completing Phase II and is preparing a presentation for the Transportation Department before initiating the project's final phase. Since RIMS is presently being used by over 200 municipalities in Ontario, the EMR's GIS Division hopes that these other sites will look at 1:50,000 topographic data as a potential source of data for such applications.

In addition, whithin the municipal context, the project team hopes that the various departments will, through the GIS, incorporate their data so that decision-making can be enhanced through a wider choice of readily available data. In the practical context, the pilot project is being designed so that end users will be able to generate various scenarios on a yearly basis to assist them in budget deliberations.

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Processus de sélection et de modification des données cartographiques pour la réalisation d'un SIRS

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Résumé

La structure des grandes bases de données à référence spatiale est aujourd'hui bien maîtrisée lorsqu'il s'agit d'implanter un système d'information à référence spatiale (SIRS) à partir du néant. Cependant, cette opération est beaucoup plus complexe lorsqu'il faut utiliser et intégrer des données existantes provenant de différentes sources. Le but de cet article est de présenter un processus de sélection et de modification des données cartographiques qui tient compte des nombreux critères d'incompatibilité de données.
Pour y parvenir le processus d'intégration prévoit notament: un inventaire de données, la définition d'un système cible, une évaluation qualitative, une analyse de compatibilité et un processus de sélection de données et enfin les transformations nécessaires à l'intégration proprement dite des données au système cible en respectant les coûts, les délais et les ressources disponobles au projet.
Cette recherche permettra de résoudre de façon structurée un problème fondamental qui préocupe tout analyste impliqué à un projet d'implantation de SIRS.

Abstract

The structure of the larger spatial databases is today well enough mastered to be allow us to implement a Spatial Information System (SIS) without access to existing data. However, this operation is a lot complex when we do have to use and integrate existing data arising from different sources.
The point of this article is to present a spatial data integration process that takes in consideration the numerous data incompatibility criterias.
To be able to do so the integration process is based on the following elements: a data inventory, the definition of the target system, a compatibility analysis and a data selection process, and finally the informations necessary to the integration itself of the data to the target system considering the costs, delays and the resources available for the project.
This publication should help any analyst to structurally resolve any problem he may face when involved in a Spatial Information System implementation project.

INTRODUCTION

L'avènement de l'informatique, et notamment des logiciels GIS (Geographic Information System) permet aux gestionnaires du territoire d'améliorer leurs modes de production et de gestion de l'information et ainsi d'accroître l'efficacité de leurs organisations. Or, un logiciel GIS ne peut à lui seul prétendre être le grand responsable de cette amélioration. Au contraire, un logiciel GIS sera efficace dans la mesure où les données qu'il gèrera, via sa base de données à référence spatiale (BDRS), permettront aux utilisateurs d'être adéquatement informés (Parent 1989).

Lorsqu'il s'agit d'implanter un système d'information à référence spatiale (SIRS) utilisant la technologie GIS à partir du néant, il est relativement facile d'acquérir (i.e. capter et saisir) les données à référence spatiale appropriées à nos besoins. Cependant, cette opération est beaucoup plus complexe lorsqu'il s'agit d'utiliser et d'intégrer des données existantes provenant de différentes sources. Deux questions se posent alors: (1) "Quelles données seront intégrées au système à implanter?" et (2) "Comment cette intégration sera rendue possible?". Très peu de travaux ont porté sur une méthodologie structurée pour la récupération de données cartographiques existantes; cette opération se fait habituellement en fonction d'une situation très spécifique et selon l'expérience et l'intuition des analystes impliqués.

Le présent texte propose un processus générique de sélection et de préparation des données cartographiques pour la réalisation d'un SIRS (informatisé il va sans dire). Après avoir cerné la problématique d'intégration de données cartographiques multisources, les auteurs définissent l'objectif de leur recherche et en présentent le résultat, c'est-à-dire le processus développé. Précisons enfin qu'il s'agit là de l'approche conceptuelle du problème par opposition à l'approche purement physique (ex.: tansfert de SIF à DXF) souvent perçue à tort comme la première difficulté.

PROBLÉMATIQUE

Nous définissons dans cette section l'intégration des données cartographiques telle que nous la concevons et nous mettons en contexte les principaux facteurs qui ont suscité notre intérêt pour cette recherche. Il est également question des problèmes inhérents à l'intégration de ces données.

Définition et mise en contexte

L'intégration des données cartographiques ici discutée réfère à *l'incorporation de données existantes, provenant de sources multiples, dans un système cible c'est-à-dire une BDRS.* (N.B.: l'intégration ne signifie pas nécessairement une centralisation des données; elle consiste plutôt à rendre les données échangeables (Nyerges (1989)). Cette opération peut sembler simple lorsqu'il s'agit d'intégrer des données provenant de deux, trois ou quatre

collections de documents cartographiques différentes mais elle est très complexe lorsque les données existantes proviennent de dizaines voir même de centaines de collections de documents cartographiques (Parent et Ouellet 1991), surtout lorsque celles-ci couvrent totalement ou partiellement le même territoire, contiennent des entités identiques ou similaires, etc.

Il existe trois scénarios d'intégration différents pour des documents couvrant un même territoire. Nous avons d'abord le cas où différents types d'entités cartographiques sont chacun représenté sur un document cartographique différent. Bien qu'elle semble être plus évidente que les autres, cette situation n'en est pas moins complexe. La figure "1a" illustre ce scénario. Nous avons également le cas où un même type d'entité cartographique est décrit par des attributs différents répartis sur plusieurs documents cartographiques. La figure "1b" illustre ce scénario. Enfin, comme l'illustre la figure "1c", nous avons le cas où la même type d'entité, décrit par les mêmes attributs, est représenté sur plusieurs documents cartographiques différents. Ces trois scénarios reflètent bien certains problèmes avec lesquels nous aurons à composer avant de procéder à l'intégration des données sources dans le système cible. Navathe, Elmasri et Larson (1986) tout comme Nyerges (1989) identifient en partie ces scénarios.

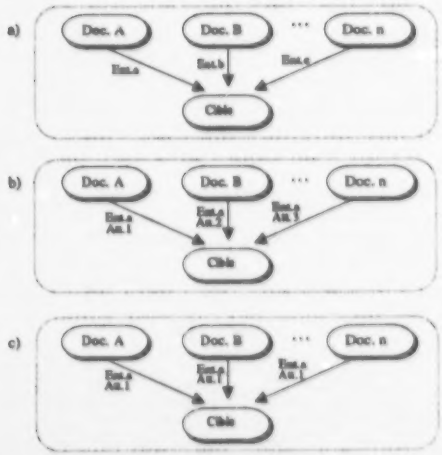

figure 1

Parce que les grandes organisations se sont historiquement développées selon des structures rigides où chacune des divisions était responsable de l'acquisition et de la gestion de ses propres données (Allam, Otoo et Chaly 1990), il y a eu dans le passé une prolifération de la production de documents cartographiques, ce qui a aujourd'hui pour conséquence d'accroître la complexité des opérations d'intégration de données. De plus, ces structures organisationnelles disposaient de peu de moyens pour encourager le partage voir même les échanges de données entre les départements qui les composaient. À la limite, on pouvait compiler les données provenant de quelques documents différents mais ces compilations cartographiques se limitaient souvent aux données avec lesquelles on était familier. Ainsi, par exemple, une division d'arpentage foncier pouvait, sans trop de difficulté, intégrer des données relatives au cadastre et à la topographie. De la même manière, le service de l'ingénierie pouvait compiler sur une base cartographique les réseaux de distribution d'électricité, de gaz naturel et d'aqueduc. Mais l'intégration des données se limitaient généralement à des applications "intra-division". Aujourd'hui, la réalité est tout autre et plusieurs raisons expliquent ce revirement de situation.

On pourrait mentionner la révolution informatique et technologique de la dernière décennie qui nous a fourni des moyens d'acquisition et de gestion des données cartographiques à la mesure de nos nouveaux besoins. Ainsi, l'avènement des systèmes de positionnement global GPS, de la photogrammétrie numérique, des systèmes de gestion de bases de données (SGBD), ainsi que de cartographie numérique ont transformé les modes de production et de gestion de l'information, mais sans toutefois modifier significativement les communications internes des grandes organisations.

L'arrivée des logiciels GIS, par contre, a donné naissance ou du moins a coïncidé avec une approche plus globale de la gestion des données sur le territoire. Ainsi est-il aujourd'hui non seulement possible mais souhaitable que l'intégration des données cartographiques s'étende au delà des divisions organisationnelles. Un département d'ingénierie peut par exemple utiliser avec plus de facilité les données provenant d'un département de l'environnement, de l'évaluation et/ou de l'arpentage foncier.

Cette contribution technologique comporte cependant certains risques. Comme le mentionne Parent (1989) "*...the greatest value of a GIS, wich offers the ability to process and transform information, is also one of the most dangerous pitfalls*". En effet, l'échange de données cartographiques suppose la connaissance des données externes à un département, ce qui n'est malheureusement pas toujours le cas, et l'utilisation et l'interprétation des données étrangères peut contrecarrer l'effet synergique visé par la gestion globale des données. L'intégration des données cartographiques en un système planifié globalement pour l'organisation favorise un partage plus "intelligent" des données.

Outre les possibilités technologiques actuelles, un autre facteur motive l'intégration des données cartographiques existantes: le coût d'acquisition des données à référence spatiale. En effet, la majorité des coûts d'implantation d'un SIRS sont imputables à l'acquisition (i.e. le captage et la saisie) des données à référence spatiale (Beaulieu et al. 1990). La récupération des données existantes, afin de les intégrer à un système cible

(i.e. une BDRS) s'avère donc généralement un moyen intéressant de diminuer le fardeau financier de l'implantation d'un SIRS.

Problèmes inhérents à l'intégration des données cartographiques existantes

Comme nous l'avons déjà mentionné, la récupération des données cartographiques existantes à des fins d'incorporation dans un système cible peut s'avérer une solution avantageuse pour diminuer les coûts d'acquisition des données à référence spatiale. Or, certains problèmes viennent compliquer cette opération de récupération et d'intégration des données existantes. Ces problèmes consistent notamment: (1) au phénomène de redondance de données et (2) à l'incompatibilité entre une donnée source et une donnée cible (i.e. souhaitée dans la BDRS à implanter).

La redondance de données

En raison du passé plutôt hermétique des départements qui composent les grandes organisations, nous rencontrons un phénomène de *duplication de l'information* lorsqu'il s'agit d'implanter une BDRS à partir de données existantes (Parent et Ouellet 1991; Larrivée, Bédard et Labbé 1991; Nyerges 1989; Navathe, Elmasri et Larson 1986).

Ce problème de redondance de données exige que l'on prévoit un processus de sélection des données cartographiques afin que seules les données les plus appropriées soient intégrées au système cible (Hallen 1991). C'est en mesurant le degré de compatibilité des données sources avec les données souhaitées dans la BDRS à implanter que l'on détermine les données qui seront retenues pour l'intégration (Hallen 1991; Parent et Ouellet 1991).

L'incompatibilité des données

Ce phénomène se définit par des *différences d'ordres conceptuel et physique entre une donnée d'un document source et celle de la BDRS à implanter*. Par exemple, les coordonnées de la position d'une entité référant au datum planimétrique NAD 27 (document source) sont incompatibles avec les coordonnées de la position de la même entité selon le datum planimétrique NAD 83 (document cible). Le niveau de compatibilité avec le système cible varie d'une donnée source à l'autre (Sévigny et Bédard 1991) et il est mesuré via les méta-données, c'est-à-dire les données qui décrivent les caractéristiques d'une donnée ou d'un ensemble de données.

On compte à ce jour environ 60 méta-données se rapportant aux entités spatiales (Bédard 1990, Prince 1990). On regroupe ces méta-données en huit grandes familles soient les méta-données se rapportant à:

- *l'identification de l'entité spatiale*
- *la description de l'entité spatiale*
- *la référence spatiale de l'entité spatiale*

- *la référence temporelle de l'entité spatiale*
- *la description de l'incertitude*
- *la description de la source;*
- *la description de l'utilisation;*
- *la description de la représentation.*

Les méta-données seront d'une utilité précieuse pour sélectionner les données cartographiques à intégrer à la BDRS cible ainsi que pour préparer l'intégration de ces données.

OBJECTIF ET RÉSULTAT OBTENU

Ayant relevé les principaux problèmes conceptuels inhérents à l'intégration des données cartographiques existantes dans une BDRS cible, nous avons fixé comme objectif de **développer un processus structuré et générique de récupération des données cartographiques existantes afin: (1) de sélectionner les données qui seront intégrées et (2) d'identifier les opérations nécessaires pour réaliser l'intégration.**

Pour élaborer ce processus de sélection et de préparation des données cartographiques, nous avons mis l'emphase sur l'aspect conceptuel du problème, c'est-à-dire comprendre "quoi" intégrer plutôt que comment. Néanmoins, la démarche proposée facilitera l'intégration physique des données cartographiques, que celles-ci réfèrent aux attributs conventionnels ou géométriques des entités spatiales cartographiées.

Le processus développé se divise en deux modules majeurs: la sélection des données cartographiques existantes et la modification des données cartographiques existantes.

La sélection des données cartographiques existantes

La sélection vise essentiellement à identifier les données cartographiques existantes qui seront les plus avantageuses à intégrer à la BDRS cible. Le résultat permet de connaître la provenance exacte des données retenues ainsi que leurs métadonnées. Ce module comprend cinq étapes: (1) la définition du système cible, (2) la sélection préliminaire, (3) l'analyse de compatibilité, (4) la sélection finale et enfin, (5) la création d'un dictionnaire des méta-données (DMD).

La définition du système cible

Cette étape consiste à définir les données cartographiques à intégrer au système cible ainsi que les métadonnées qui décrivent ces données. Il s'agit d'abord de circonscrire les entités que nous souhaitons retrouver dans le système à implanter ainsi que les attributs

conventionnels et géométriques qui décriront ces entités (Hallen 1991, Parent et Ouellet 1991). Pour y parvenir, nous utilisons les résultats obtenus lors d'étapes antécédentes pour la réalisation d'un SIRS, soit le dictionnaire des données descriptives (DDD), le dictionnaire des données cartographiques (DDC) et le modèle conceptuel de données (MCD) du système cible ainsi que les autres résultats de l'inventaire de l'existant (voir la figure 2).

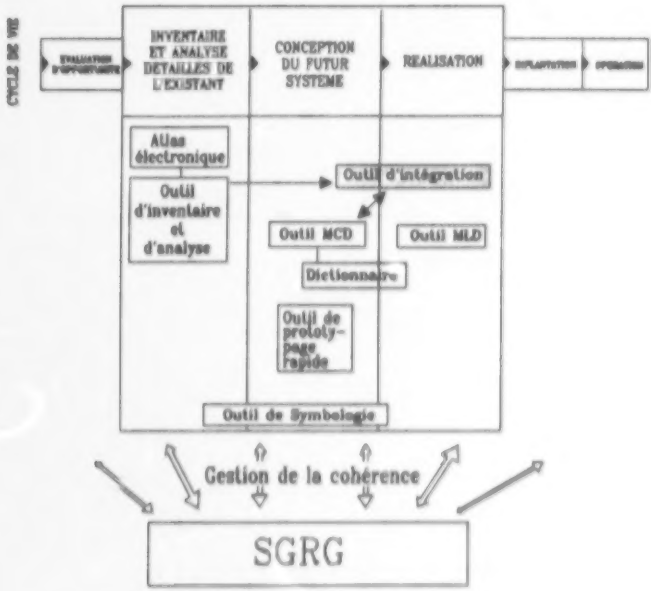

figure 2: Lien entre l'outil d'intégration et les autres outils CASE en développement au Centre de géomatique de l'Université Laval

À cet effet, il faudra utililiser une terminologie sémantiquement cohérente tout au long du processus, tant pour les noms d'entités que pour leurs attributs (Nyrges 1989, Guthrie 1991, Chevallier 1990).

Il faut également préciser à quelle(s) fin(s) nous souhaitons retrouver dans notre futur système les attributs identifiés, surtout pour évaluer si la qualité des données sources est suffisante. De plus, des huit grandes familles de métadonnées précédemment identifiées, nous suggérons d'établir pour chacune des données de la BDRS cible les métadonnées suivantes:

Les métadonnées qui décriront la position des entités cartographiques: le datum planimétrique, le datum altimétrique, l'ellipsoïde de référence, le système de coordonnées, la projection cartographique, l'unité de mesure, la précision et la date de relevé ou de mise-à-jour.

Les métadonnées qui décriront la forme des entités cartographiques: la description géométrique, la précision et la date de relevé ou de mise-à-jour.

Les métadonnées qui décriront la description des entités cartographiques: les valeurs possibles, la longueur et le type de l'attribut, l'unité de mesure et la date de relevé ou de mise-à-jour.

Les métadonnées qui décriront la représentation des entités cartographiques: l'échelle, la base cartographique, le type de support, le système d'exploitation et le découpage cartographique.

La sélection préliminaire des données

L'étape de sélection préliminaire se divise en trois sous-étapes: (a) la requête dans la base de données d'inventaire, (b) l'évaluation de la qualité et (c) l'évaluation de la représentation.

a) La requête dans la base de données d'inventaire

Cette sous-étape consiste à trouver parmi les collections de documents cartographiques existantes toutes celles qui contiennent au moins un attribut d'une des entités désirées. Les données obtenues seront toutes susceptibles de servir, seules leurs méta-données permettront d'éliminer des solutions possibles.

b) L'évaluation de la qualité des données retenus

On peut évaluer, de façon relative, l'incertitude des données en évaluant les paramètres qui introduisent cette incertitude. Les métadonnées deviennent donc utiles à l'analyse de la qualité des données. Le but d'une collection de documents, les thèmes qu'on y retrouve, la méthode d'acquisition des données, la satisfaction moyenne des utilisateurs, les normes de captage, de conception, de représentation et le producteur d'une collection de documents sont des métadonnées qui renseignent explicitement l'analyste sur la qualité, relative à ses besoins d'application, des données décrites par les collections de documents. Par contre, l'unité de mesure, la date de relevé, la description géométrique, les valeurs possibles pour un attribut, sont des exemples de métadonnées pouvant informer implicitement l'analyste sur la qualité des données (toujours en fonction de ses besoins d'application).

Il s'agit ensuite de sélectionner parmi les collections de documents analysées, celles dont la qualité des données est présumée supérieure par rapport aux besoins identifiés lors de la définition du système cible.

c) L'évaluation de la représentation des données

Il s'agit de sélectionner parmi les collections retenues, celles dont l'échelle, la base cartographique, le type de support, le système d'exploitation (s'il y a lieu) et le découpage sont globalement le plus approprié par rapport système cible.

L'analyse de compatibilité

Cette étape évalue les données des collections de documents sélectionnées en terme de compatibilité, par rapport aux données du système cible (Nyerges 1990, Hallen 1991). Les métadonnées de position, de forme et de description des entités spatiales représentées sur les collections sources préliminairement sélectionnées sont comparées aux métadonnées souhaitées pour la BDRS cible. Regroupées dans une grille d'analyse semblable à celle proposée par Parent et Ouellet (1991), ces métadonnées serviront à la sélection finale des données. Des travaux très détaillés en ce sens ont également été réalisés par Sévigny (1992).

La sélection finale

La sélection finale a le double objectif de déterminer la provenance des données qui seront intégrées dans le système cible et de minimiser le nombre de documents d'où origineront ces données. Cette étape se divise en trois sous-étapes: (a) l'évaluation des efforts d'intégration, (b) la cotation des collections de documents potentiellement utiles à l'intégration (CPUI), (c) la sélection des collections de documents utiles à l'intégration (CUI).

a) Évaluation des efforts d'intégration

L'intégration des données à référence spatiale existantes en vue d'édifier un système cible (une BDRS) est une opération tributaire des agents, des délais et des ressources (humaines, matérielles et financières). Cela dit, on doit prévoir l'effet de ces contraintes sur la gestion du projet et sur les choix à faire au cours de sa réalisation.

En effet, il est important d'utiliser au maximum les données cartographiques existantes mais il ne faut pas récupérer aveuglément ces données; tendre vers un minimum d'effort d'intégration est un objectif sain pour tout analyste soucieux d'assurer une saine gestion de son projet. Puisqu'il faudra transformer les données sources pour les rendre "intégrables" au système cible (transformer un système de coordonnées, une projection cartographique, mettre à jour une

donnée, ...) on doit anticiper des efforts à fournir (en coûts, en délais et en ressources), efforts qui sont plus ou moins significatifs d'une donnée à l'autre.

L'évaluation de ces efforts se fait en analysant la grille de compatibilité de chaque attribut et en octroyant à chaque méta-donnée une pondération correspondante à l'effort à fournir et à l'ordre d'importance de la contrainte. Il suffit ensuite de faire la somme par collection des efforts à fournir pour chaque attribut de chaque entité. L'évaluation des efforts d'intégration repose, il va sans dire, sur une pondération relative.

b) Cotation des collections potentiellement utiles à l'intégration (CPUI)

La somme des efforts d'intégration nous indique l'effort global (en terme de coûts, de délais et de ressources) qu'il faudra consacrer à la transformation des données contenues sur les collections de documents potentiellement utiles à l'intégration (CPUI).

La cotation des CPUI consiste à appliquer une cote aux CPUI, laquelle cote varie en fonction de l'effort global d'intégration des données contenues sur ces documents. Inscrites dans des grilles, ces cotations des CPUI par attribut sont ensuite compilées dans des grilles de cotation des CPUI par entité qui sont à leur tour compilées dans une grille de cotation globale des CPUI.

c) Sélection des collections de documents utiles à l'intégration (CUI)

Il s'agit de reprendre la liste des entités et attributs à intégrer au système cible, de choisir, dans la grille de cotation globale des CPUI, la collection la mieux cotée et d'identifier les attributs qu'elle contient.

Identifier ensuite cette collection vis-à-vis les attributs en question et inscrire la cote qu'a obtenu cette CPUI pour ces attributs (en référant à la grille de cotation des CPUI par attribut). Reprendre le processus avec la collection dont la cote globale est immédiatement inférieure et ainsi de suite.

Lorsqu'on a identifié une CPUI et la cote de cette CPUI par attribut pour tous les attributs de toutes les entités, nous avons sélectionné les collections de documents qui serviront finalement à l'intégration des données sources dans le système cible, c'est-à-dire les collections de documents utiles à l'intégration (CUI). Cependant, la solution n'est peut être pas la meilleure.

Il s'agit d'optimiser la solution en vérifiant s'il existe, parmi les CUI sélectionnés, une collection de meilleure cote pour fournir un attribut (en référant à la grille de cotation des CPUI par attribut). Apporter la correction (s'il y a lieu) en identifiant cette CUI.

Voilà brièvement la description des différentes étapes du processus d'intégration des données à référence spatiale dans les cartes numériques, processus qui

permet de connaître la provenance des données existantes qui seront intégrées dans le système cible. Les étapes à venir sont consacrées à savoir comment se fera l'intégration.

La création du Dictionnaire des MétaDonnées (DMD)

Connaissant la provenance des données existantes qui seront intégrées au système cible, nous pouvons créer un DMD. L'étape de création du DMD consiste à répertorier toutes les méta-données se rapportant aux données retenues, ce qui permettra à tout moment de connaître l'origine des données du nouveau système (Parent 1989, Hunter et Williamson 1990, Hallen 1991). Le DMD peut-être généré automatiquement à partir d'une base de données informatisée d'inventaire ou encore créé manuellement, si le contenu de l'inventaire des données existantes n'est pas informatisé. Le DMD servira également à connaître ce qui en est vraiment des modifications à faire sur les méta-données des données sources avant de les intégrer.

La modification des données cartographiques existantes

Le module de modification permet de préparer les données pour leur intégration au système cible (Parent et Ouellet 1991, Lankford et D'Ambrioso 1990, Hallen 1991). Changer un système de référence, convertir une unité de mesure, modifier les valeurs possibles pour un attribut donné ne sont là que quelques exemples de modifications à apporter aux méta-données. Le DMD permet d'identifier les modifications nécessaires. Cependant, parce qu'il existe une multitude de solutions selon le contexte et les ressources disponibles d'une organisation, trouver les façons de réaliser ces modifications dépasse le cadre de l'actuelle recherche.

Voilà en quoi consiste le processus de sélection et de modification des données cartographiques pour la réalisation d'un SIRS. La figure 3 présente la structure de ce processus.

CONCLUSION

Le processus de sélection et de préparation des données cartographiques pour la réalisation d'un SIRS, tel que sommairement présenté dans ce texte, permet de résoudre de façon structurée un problème complexe avec lequel doit composer tout analyste impliqué dans un projet d'implantation de SIRS.

Bien qu'il permette la récupération des données cartographiques selon un cadre formel, le processus possède une certaine souplesse, ce qui lui procure l'avantage d'être adaptable à tout inventaire sérieux des données existantes.

Le processus présenté prévoit des boucles de rétroaction. Ces boucles de rétroaction permettent de réévaluer les différents critères de sélection afin notamment de: (1) diminuer une liste trop exhaustive de collections de documents sélectionnées, (2) accroître une liste trop restreinte de collections de documents sélectionnées, ou encore (3) de s'assurer que l'ensemble des collections de documents sélectionnées pour récupérer une donnée cartographique couvrent la totalité du territoire concerné. Au moment de la publication de cet article, le processus détaillé devrait apparître dans le mémoire de M.Sc. du principal auteur.

Enfin, nous remercions les compagnies Intergraph et Gendron-Lefebvre ainsi que le CRSNG qui ont contribué au financement de cette recherche.

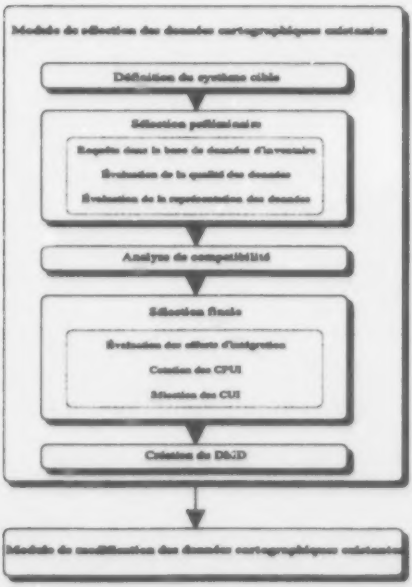

figure 3

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Proposition de conférence pour GIS '92 (séance régulière)

SIRS à petite échelle pour les décideurs municipaux

Small-scale GIS for municipal decision-makers

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Résumé

La contribution présente le système d'information à référence spatiale (SIRS) développé pour la Direction générale et les directeurs des services de la Ville de Laval (Québec), dont l'objectif est la mise à disposition des hauts responsables de cette villes de près d'un demi-million d'habitants un outil d'aide à décision basé sur une référence spatiale commune, homogène et fiable.

Pour succéder aux actuelles cartes de ville au 1:25,000 et 1:50,000, la Ville de Laval s'est dotée d'un SIRS moderne, conçu en fonction des besoins des décideurs du niveau stratégique d'une grande municipalité. Ce système se base sur la cartographie au 1:20,000 du MERQ et sur d'autres bases gouvernementales (Statistiques Canada, en particulier), soigneusement validées, homogénéisées et mises à jour. Implanté sur leur ordinateur personnel (Apple ou IBM compatible) à côté du traitement de textes, du tableur et de la base de données administratives, cet outil de "géobureautique" fournit aux intéressés une réponse à leurs besoins pour la gestion et la planification stratégique.

Ce rapport est destiné aux décideurs municipaux et aux consultants; il montre comment un tel outil géomatique peu coûteux peut être un précieux apport pour la prise de décisions de grande importance.

Summary

This paper present a Spatial Information System (SIS) developed at Ville de Laval (Québec) for the General City Manager and the Directors of the municipal services. Its goal is to bring to these decision-makers adequate information and analysis tools, based on a common, homogenous and up-to-date spatial reference across that 400,000 inhabitant city.

This modern SIS is designed according to strategic decision-making needs, and should replace the traditional city maps in scale 1:25,000 and 1:50,000. This system is based

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upon the provincial 1:20, 000 cartography merged with other governmental data sets (e.g., Statsitics Canada addresses files), after a careful validation, homogenization and updating process. Implemented on the decision-maker's PC or Mac, side-by-side with the text-processor, the spreadsheet and the data base, this "geobureautic" tool brings a quick and powerful response to strategic management and planning questions.

This paper is designed for municipal authorities and consultants; it shows how such a low-cost geomatic tool might bring a highly-prized contribution for long term and cost-effective decisions.

An Object Base Implementation of a Spatial Topological Data Model

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Abstract

Geographic Information Systems (GIS) may be perceived as composed of a collection of analysis functions that operate on a stored collection of geographic features, i.e., spatial objects. The collection is complete with visualization tools for depicting graphically the results of analysis, real-time effects of operations and responses to queries on these spatial objects. We term as an *object base* any repository of object whose interaction with the outside world is only through message passing. The multifaceted nature of the data types required in a Geographic Information Systems appears then to strongly favour the use of an *Object Base Management System* to provide the underlying object management functions on which a GIS can be implemented.

Unfortunately there are still some serious drawbacks that need to be resolved before the full potential of an object base can be harnessed to facilitate the design and implementation of a GIS software and subsequently, GIS applications. While the object oriented programming methodology is very much matured and is now used in developing highly reliable large scale software, the object base (or an object oriented database) still lacks the uniform consensus, within the database community, for both its architecture and conceptual modeling techniques. Further, for most available systems, the mapping of GIS applications onto the underlying object classes results in unwarranted data replication and redundancy. This paper presents a framework of an object base suitable for mapping a spatial topological data model onto the underlying classes without undue data redundancy, replication and expensive storage overhead. We demonstrate the unique properties of the framework and show how spatial features and their associated methods are mapped onto classes of the underlying object base.

Mise en oeuvre d'une base d'objets pour un modèle de données topologiques spatiales

RÉSUMÉ

Les Systèmes d'information géographique (SIG) peuvent être perçus comme étant constitués d'un ensemble de fonctions d'analyse qui régissent un ensemble de données stockées, relatives aux caractéristiques géographiques, c.-à-d. aux objets spatiaux. Le système est complété par des outils de visualisation pour représenter graphiquement les résultats des analyses, les effets des opérations en temps réel et les réponses aux questions sur ces objets spatiaux. Nous appelons «base d'objets» tout dépôt d'objets dont l'interaction avec le monde extérieur ne se fait que par transmission de message. Le caractère à multiples facettes des divers types de données requises dans un Système d'information géographique semble favoriser fortement l'utilisation d'un «Système de gestion de la base d'objets» permettant d'assurer les fonctions sous-jacentes pour la gestion des objets, grâce auxquelles un SIG peut être mis en oeuvre.

Il reste malheureusement encore quelques problèmes à résoudre avant de pouvoir maîtriser toutes les possibilités d'une base d'objets en vue de faciliter la conception et la mise en oeuvre d'un logiciel SIG et, ultérieurement, les applications SIG. Même si la méthodologie de programmation axée sur l'objet est pratiquement arrivée à maturité et est déjà utilisée pour l'élaboration de logiciels à grande échelle très fiables, la base d'objets (ou base de données axée sur les objets) n'a pas encore été acceptée unanimement par la communauté des bases de données, aussi bien à cause de son architecture qu'en raison de ses techniques de modélisation conceptuelle. De plus, pour la plupart des systèmes disponibles, la cartographie des applications SIG sur les diverses classes d'objets sous-jacentes entraîne un double emploi et une redondance injustifiés. Le présent document présente un cadre d'une base d'objets pouvant convenir à la cartographie d'un modèle de données topologiques spatiales sur les classe sous-jacentes, sans redondance ni double emploi pour les données, ni stockage coûteux en amont. Nous démontrons les propriétés uniques du cadre et indiquons comment les caractéristiques spatiales, avec les méthodes associées, sont cartographiées sur les diverses classes de la base d'objets sous-jacente.

ABSTRACT OF PAPER PROPOSED FOR GIS 92

DIGITAL CHART OF THE WORLD (DCW): WORLD WIDE APPLICATIONS

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The Digital Chart of the World (DCW) R&D Project is a joint project between Australia, Canada, the United Kingdom and the United States of America. The DCW was designed for military, scientific and educational applications with regional, continental and global analysis capabilities. Principal applications could range from environmental assessment through to third world infrastructure and transportation planning.

This paper will discuss in detail the various potential applications of DCW data, related standards and generic viewer software which will be available for world wide public domain distribution in February 1992, at minimal cost.

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Carte numérique du monde (CNM) : applications à l'échelle mondiale

RÉSUMÉ

La carte numérique du monde (CNM), est un projet R & D conjoint de l'Australie, du Canada, du Royaume Uni et des États-Unis d'Amérique. La CNM a été conçue à des fins militaires, scientifiques et éducatives avec des moyens d'analyse à l'échelle régionale, continentale et mondiale. Les principales applications pourraient aller de l'évaluation environnementale jusqu'à la planification des transports et de l'infrastructure pour le tiers-monde.

La présente communication examine en détail les diverses applications possibles des données de la CNM, les normes connexes et le logiciel à l'intention du public en général, qui sera prêt pour diffusion dans le public dès février 1992, à un coût minime.

DIGITAL CHART OF THE WORLD (DCW)

CANADIAN DATA SAMPLER CD-ROM PROTOTYPE

by

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ABSTRACT

The Digital Chart of the World (DCW) is an international R & D project whose main objective is the promulgation of DIgital Geographic information Exchange STandards (DIGEST); both by developing technical standards and by backing them up with a large vector database encoded in the Vector Relational Format (VRF) of DIGEST. DCW will provide a seamless coverage of the entire world at 1:1 000 000 scale on four CD-ROMs and will be released, with its own application software, into the public domain in May 1992. The Department of National Defence is developing a Canadian Data Sampler CD-ROM prototype, compatible with the DCW VRF format in order to test the use of digital map data at different scales. This paper lists the possible map data products, describes the development options, outlines the implementation plan, and indicates the benefits of this prototype for Canada.

RESUME

La Carte Numérisée du Monde (DCW) est un project international de recherche et de développement dont le but principal est la promulgation des standards pour l'échange d'information géographique numerisée (DIGEST); en développant les standards techniques et en les renforcant par une large bande de données encodées dans le format relationel vectoriel de DIGEST. Le produit DCW fournira une couverture sans couture du monde entier a l'échelle 1:1 000 000 sur quatre disques CD-ROM et sera mis en circulation, avec son propre logiciel d'application, dans le domaine publique en mai 1992. Le Ministère de la Défense Nationale développe un prototype d'un modèle de données canadiennes sur disque CD-ROM, compatible avec le format de DCW, afin de mettre à l'épreuve l'utilisation de cartes numérisées à differentes échelles. Ce papier liste les produits cartographiques potentiels, décrit les options de développement, esquisse le plan d'implémentation, et indique les bénéfices pour le Canada.

INTRODUCTION

The Digital Chart of the World (DCW) is a four nation research and development project between Australia, Canada, the United Kingdom, and the United States. The Canadian participants are the Department of National Defence (DND), the Department of Energy, Mines and Resources (EMR), and the Department of Fisheries and Oceans (F&O). The objectives of the DCW project are:

- to develop and establish standards that will enable the exchange of user oriented digital geographic information;
- to develop a set of evolving product prototypes suitable for technical and utility evaluation;
- to develop prototype applications software sufficient to support the testing and evaluation of the product prototypes; and
- to develop an initial worldwide digital vector database; that will support future product development and initial implementation.

The first three objectives have been met and the DCW production is nearing completion. The DCW product is being developed by the Environment Systems Research Institute (ESRI) in California and will be released in May 1992, with its application software and source code. Accessible using PC-based systems, the DCW will include over 1.5 gigabytes of geographic data in a topologically structured vector format, providing a complete digital representation of the earth's land surface on four CD-ROMs. The worldwide coverage is being derived from the Operational Navigation Chart (ONC) series of aeronautical charts, of which coverage over Canada is derived from the World Aeronautical Charts (WACs), an EMR product. The georeferenced DCW database will contain all the features and attributes normally displayed on the ONC chart.

However, a recent project review determined that the DCW standard effort was not complete and that some additional work was required to firmly establish the Vector Relational Format (VRF) of DIGEST as an international standard. With the data, viewer software, and source code in the public domain, a vast number of GIS users are expected to adopt DCW and eventually produce data compatible with the DCW VRF format.

VRF is a generic data model designed to be used with any geographic data in vector format that can be represented using nodes, edges, or faces. It is also designed to provide flexibility in encoding, accessing, and modelling digital geographic databases for a variety of GIS applications on different computer platforms. VRF is only one of three formats of the DIGEST standard and is

basically an encapsulation of DIGEST format in terms of relational tables.

A significant number of spatial digital databases exist within the various levels of government in Canada. These databases have been compiled at different scales and produced in varying formats. The Department of National Defence has therefore undertaken the development of a Canadian Data Sampler (CDS) on CD-ROM in order to test the validity of the VRF format with various digital map data at varying scales, and to verify the ease of utilization of the DCW viewer software with other databases. In cooperation with other federal, provincial, regional, and municipal government agencies, the following databases have been suggested for inclusion in the CDS prototype:

- EMR National Atlas at 1:7 500 000 and 1:2 000 000;
- Canadian Coverage of DCW at 1:1 000 000;
- EMR Geological Thematic Bedrock on at 1:1 000 000;
- Ontario Hydro Facilities Map at 1:600 000;
- F&O Canadian Hydrographic National Resources at 1:250 000;
- EMR National Topographic Series at 1:250 000 and 1:50 000;
- Statistics Canada Area Master File at 1:50 000;
- National Capital Commission at 1:25 000 and 1:2 000;
- Ontario Ministry of Natural Resources at 1:10 000; and
- DND MCE Training Area Maps of Wainwright and Petawawa at 1:50 000 including the Tactical Terrain Analysis Data Base (TTADB) overlays.

The coordination of the above datasets was initiated by the Geographic Information Systems Division. The majority of the datasets are of the Ottawa National Capital. The datasets from F&O and Geological Surveys are of British Columbia and Quebec respectively; the military datasets are as stated.

CANADIAN DATA SAMPLER DEVELOPMENT

DND's Directorate of Geographic Operations has contracted the production of the CDS prototype to IDON Corporation of Ottawa due to their working knowledge and experience with the DCW project and DIGEST standards. While attempting to coordinate the integration of the different types of data from various sources, and in parallel attempting to develop new procedures for the production of VRF compatible data, it was deemed not viable. Therefore, to facilitate and expedite the development of more formalized procedures, IDON decided to select one of the proposed databases as a model for the CDS prototype. The entire CDS project is being funded by DND, thus the database selected for the model is the military training area map data of Wainwright, Alberta at the scale of 1:50 000. Wainwright is the major training area for the Canadian Forces and the location for Rendez-Vous exercises, divisional-size manoeuvres take place every two years.

The plan to convert the Wainwright data from its original format of INTERGRAPH IGDS to DIGEST VRF has been divided into eight basic tasks as outlined below:

1. Convert the data from its current IGDS format into the INTERGRAPH interchange format ISIF.

2. Data pre-processing and ARC/INFO GIS input.

3. Create/populate ARC/INFO and VRF data dictionary tables.

4. Translate the feature attributes.

5. Generate product specifications for the CDS prototype.

6. Clean the data and build the topological relationships using ARC/INFO.

7. Develop a front viewer software based on DCW.

8. Convert the database from ARC/INFO to VRF format using the conversion software developed by ESRI.

CANADIAN DATA SAMPLER IMPLEMENTATION

The original plan for the CDS was to integrate all datasets over the Ottawa National Capital for display at this conference. Due to time and monetary constraints, the implementation of the incremental CDS prototype has been phased in order to meet the time requirements of the various users. The proposed schedule of release is as follows:

- Prototype 1, March 1992 for the national GIS conference, to include the Canadian coverage of DCW at 1:1 000 000 scale;

- Prototype 2, May 1992 for the military exercise RV 92, to include the content of prototype 1 plus the Wainwright training area map data at 1:50 000 scale with its TTADB overlays;

- Prototype 3, August 1992 for the military Artillery Regimental Delivery System (ARDS) project, to include the content of prototype 2 plus the Petawawa training area map data at 1:50 000 scale with its TTADB overlays; and,

- Prototype 4 (final release), December 1992 to contain the inclusion of the remaining datasets.

The CDS prototype will be comprised of one CD-ROM, two diskettes with the executable and source code for the VRF viewer software, and the instruction manual. The prototypes is to be released to a selected group of users for evaluation.

While the CDS prototype is being developed in Canada, a similar project has already been initiated in the United States. The U.S. Defense Mapping Agency has contracted ESRI to produce a tactical database in VRF format known as Digital Terrain Data (DTD). The 1:50 000 DTD product is a combination of geographic data in digital layered and digital integrated terrain configurations. The objective of this project is to demonstrate the applicability of VRF to these two types of database.

The area surrounding Fort Hood in Killeen, Texas has been selected for evaluating the prototype data sets within the U.S. military. The complete Fort Hood training area is being produced on one CD-ROM but is not yet finished. At this time however a small data set covering a geographic area of 5' X 5' (about 3 Mbytes) is available and will be demonstrated at the GIS conference. The significance of this data set is that it represents a tactical scale of 1:50 000 whereas DCW provides a worldwide strategic database at 1:1 000 000.

The data created in VRF format is viewable using the software VPFVIEW which is included with DCW, the CDS prototype, and the DTD data set. VPFVIEW is not meant to be a GIS but rather a method of displaying and querying the database in a simplistic manner. A more elaborate GIS is required in order to perform complex functions. All the VPFVIEW software code has been written in the "C" language and the source code will be available to the user for incorporating additional capabilities.

CONCLUSION

The DIGEST standard has been adopted by NATO as the international geographic exchange standard, and is in the process of being submitted to the International Standards Organization (ISO). The VRF format of DIGEST represents a complete standardized format for the preparation of topologically structured vector relational data. As previously mentioned, VRF is only one of three implementation formats of the DIGEST standard, the other two are in ISO 8211 standard for archival and bulk exchange, and in ISO 8824 standard for telecommunication. Through its involvement in the Digital Geographic Information Working Group (DGIWG) and the DCW project, the Directorate of Geographic Operations has been instrumental in the development and promulgation of DIGEST.

The CDS prototype will further the efforts to promote the viability of DIGEST as an international standard and, at the same time, benefit Canada in creating a set of procedures for the integration of var

ious Canadian GIS databases into one single format, DIGEST VRF. The CDS prototype will also be distributed in the public domain with all the source code information. It is believed that this initiative will greatly assist the public and private sectors in Canada to working together towards a common GIS standard.

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Observations on a Practical and User-Focused Training Program: The Conservation Authorities of Ontario

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ABSTRACT

In between the GIS software choice and the adoption of GIS into the daily operations by any organization, lies the training that the software users require. Ultimately, the success of the GIS implementation is determined by the effectiveness of the training that is undertaken. The training program itself should be one which addresses the functionality of the specific software of choice, as well as provide an education into the concepts of spatial data processing using GIS.

In support of the Shoreline Management Program (SMP) of the Ministry of Natural Resources, 28 Conservation Authorities (CA's) in Ontario purchased GIS to assist in the implementation of the program. This came as a result of recommendations from the Provincial GIS Task Force, which also recommended that a focused training program be devised.

A number of important concepts went into the creation of the CA training program and the corresponding training databases, and included:

- applications focused on issues and geography that were familiar to the participants;
- the map scales and data sources involved were identical to those that are currently in use;
- a self-guided training book was required to accompany the course which clearly describes the objectives, procedures and presents sample output for a number of exercises; and
- the courses were to be conducted on-site, at a number of centralized CA office locations.

The reason for this overall approach was to distil the GIS training process into a series of software procedures, which transform current manual procedures into those that are done in an automated fashion within GIS, as well as maintain some consistency in the applications and work environment to allow for more effective learning.

Observations sur un programme de formation pratique, axé sur l'utilisateur : les Offices de protection de la nature de l'Ontario

RÉSUMÉ

Entre le choix d'un logiciel SIG et son utilisation pour les opérations quotidiennes d'une organisation, il y a la formation qu'il faut donner aux utilisateurs de ce logiciel. Finalement, l'échec ou la réussite de la mise en oeuvre du SIG est déterminé par l'efficacité de la formation qui est donnée.

Pour faciliter la mise en oeuvre du «Programme de gestion des rives» du ministère des Richesses naturelles, 27 Offices de protection de la nature (OPN) de l'Ontario ont acheté des SIG, et ce à la suite de plusieurs recommandations du Groupe d'étude SIG, qui avait également recommandé que l'on prépare un programme de formation pertinent.

Des visites sur le terrain ont été effectuées à un certain nombre d'OPN dans le cadre d'une étude sur les besoins initiaux de l'utilisateur, et on a caractérisé une série de domaines (par ex. introduction et examen du plan) et de méthodes d'application. Ces applications ont conduit à la création de bases de données pertinentes, qui ont constitué la base d'un programme de formation.

Un certain nombre de concepts importants ont été introduits lors de la création du programme de formation des OPN avec les bases de données correspondantes pour la formation, dont les suivants :

- les applications étaient axées sur les questions auxquelles les utilisateurs sont confrontés quotidiennement;
- les zones d'étude géographique étaient semblables à leurs propres zones;
- les échelles et les sources des cartes considérées étaient identiques à celles utilisées actuellement.

De plus, pour accompagner le cours, on a préparé un manuel d'auto-formation, qui décrit les objectifs et les méthodes et qui présente les résultats d'exemples pour un certain nombre d'exercices.

La raison de cette démarche globale était de fractionner le processus de formation SIG en une série de méthodes informatisées, autrement dit de transformer les méthodes manuelles actuelles en celles qui sont accomplies automatiquement à l'intérieur du SIG.

1.0 INTRODUCTION

Once the GIS software has been selected and the appropriate hardware and software have been purchased, the route to the successful adoption of GIS into the daily operations of an organization can be an overwhelming experience. Given that the typical user of GIS in the last few years has been shifting away from the GIS expert, to an applications-driven user, the ultimate success of the adoption of GIS by the various members of the organization into their daily operations is determined in large part by the effectiveness of the training program that is undertaken.

The training for computer-based applications software tends to focus on the technology aspects of the software, and certainly GIS has been no exception to this trend (Aronoff, 1989). This type of training is appropriate in many situations for training frequent users of computers in general and for non-GIS types of software.

The nature of GIS and spatial data processing is such that there are many fundamental principles that must be understood in addition to the purely functional aspects of the chosen software. The challenge lies in developing a training program that will progress the casual paper map user into a competent GIS user. This user would be aware of the functional aspects of the particular chosen software such that it can be effectively used to accomplish current tasks, and then progress to the advanced capabilities of GIS that could not be done in a manual situation.

This paper describes the process of developing a user-focused training program for 28 Conservation Authorities of Ontario, as well as the thoughts behind the way that the courses were developed. At the end of this paper, some observations on the devised training program as well as some comments on user acceptance will be presented. The overall intent is to provide the reader with concepts and observations as they relate to the current conventional approach to GIS training compared to a user-oriented one.

2.0 BACKGROUND

In support of the Shoreline Management Program (SMP) of the Ministry of Natural Resources, 28 Conservation Authorities (CA's) in Ontario purchased PC-based GIS in the spring of 1991, to assist in the implementation of the program. The GIS chosen was the Spatial Analysis System (SPANS) from INTERA-TYDAC Technologies in Ottawa. One critical aspect to the choice of the SPANS software was the advanced graphical user interface that has been developed in the OS/2 - presentation manager environment.

The choice of the SPANS GIS was a result of recommendations from the Provincial GIS Task Force, which undertook a GIS User Needs Study (MNR, 1991) between the spring 1990 and summer 1991. It was felt that SPANS was the GIS which best suited the needs of the SMP, as well as many of the other programs that are undertaken by the CA's on a daily basis. Geomatics International became involved in the formalized aspects of the user needs study through a contract which commenced in March 1991.

The user needs study addressed many of the technical issues of software and hardware selection, as well as the GIS functional requirements, but went further in two key aspects. The first was the creation of pilot databases that served as "proof of concepts". In the early stages of the study, a list was prepared

of the various programs that are administered by CA's which could benefit from implementing GIS. The most common applications identified such as "plan input and review", as well as general shoreline management issues related to shoreline processes and environmental impact assessment became the focus for the creation of the databases. The objective of these databases was to employ data from various geographic regions of Ontario, along with data of varying scales, themes and interests to assess technological issues such as database design, processing speed, and levels of resolution, in addition to issues of overall practicality.

The second aspect addressed in the user needs study was in the recommendation that a training program be created for the CA's which would allow for the prospective users to learn the specific GIS program using databases and applications with which they were familiar. This recommendation was made with an understanding of the importance of effective training as being a critical component to the successful adoption of the GIS by the end-user.

During the course of the user needs study, field visits were conducted at several CA offices to observe first-hand how the identified priority applications were currently being done in terms of procedures, as well as identify and characterize the supporting data sources and computer software and hardware that were employed (if at all). These visits helped to create a profile of the "typical" CA staff person that was involved in the SMP, which in itself would help to match the potential benefits of the use of the GIS software with the way in which the applications are being conducted. In other words, these first-hand observations were vital in gaining a true appreciation for the way in which the CA staff actually perform their work.

The field visits also assisted greatly in the creation and subsequent refinement of the pilot databases in regards to the data themes of importance and the way that the data should be optimally structured.

3.0 CURRICULUM DEVELOPMENT - CA TRAINING PROGRAM

The major challenge in establishing a user-focused training program is how to tailor the curriculum to the diverse needs of the people who will be either directly or indirectly involved with the GIS. In the CA's, the people involved in the SMP often have responsibilities in a number of other programs. As a result, their educational backgrounds (eg.- planning, engineering, etc.) and work experience were quite diverse. This is exemplified in the job titles of the people who participated in the training program:

- shoreline management engineer;
- engineering technician;
- supervisor of lands and operations;
- planning coordinator;
- water resource manager; and
- water resources technician.

The common thread that linked all of these GIS users together was the responsibilities and applications of the SMP.

A number of important concepts and basic requirements went into the creation of the CA training program and the corresponding training databases, and included:

- applications focused on issues and geography that were familiar to the participants;
- the map scales and data sources involved were identical to those that are currently in use;
- a self-guided training book was required to accompany the course which clearly describes the objectives, procedures and presents sample output for a number of exercises; and
- the courses were to be conducted on-site, at a number of centralized CA office locations.

The desire behind these concepts was to distil the GIS training process into at most a series of software procedures, which would in effect transform current manual procedures into those that are done in an automated fashion within GIS. Furthermore, relevance in the applications to those currently and frequently being done would allow for more effective learning, as well as to illustrate the utility and appropriateness of GIS. Having the training courses at CA offices also allows for continuity and familiarity in the work place to create an effective learning environment.

Useful information as to the potential structure and content for the training program was derived from the previously mentioned user needs study. A hardware and software survey that was sent to all CA's in Ontario, which along with the field visits, helped to uncover a number of important aspects about the CA personnel in regards to overall computer and map product usage. The "typical" CA person involved in the SMP, and that would be directly involved with the GIS can be characterized as follows:

- has a limited exposure to computers, with most CA's having one or a number of PC's around in the office;
- is probably familiar with one or more of the popular PC spreadsheet (eg.- Lotus 1-2-3), wordprocessing (eg.- Wordperfect) and database management software (eg.- dBase III), as well as some usage of AutoCAD in a mapping context; and
- is a frequent user of paper maps, employing them for many applications.

It is important to note that a handful of CA's had developed applications databases using popular PC database management software (eg.- Dbase), for use in the SMP.

Given the intentions for the training program and the supporting information that was gathered, it was felt that a series of courses would have to be developed to properly address the diverse needs of the CA personnel. In this regard, the following courses were devised:

(1) a one day orientation seminar which features a brief introduction into the concepts of GIS, the specifics of the SPANS GIS, as well as presentations of successful GIS applications projects;

(2) a three day basic introductory training course which focuses on hardware and software specifics of SPANS, and many of the data input, data storage and retrieval, as well as data manipulation and analysis capabilities; and

(3) a two day advanced training course which follows the basic introductory course and explores advanced overlay and modelling concepts, as well as point transformation techniques.

The intent behind splitting the training into a series of courses was to spread the material over a longer period than is typically in a single course offered by the software vendors. These different courses would provide the new GIS user with enough time to embrace the functionality aspects of the software technology and many new concepts behind spatial data processing. It was felt that the learning experience and retention of the material would be more effective, as opposed to having to grasp all of the material in a short and intense training course in which all aspects of the software are taught during a single session. In this situation, the learning experience for most people has the potential for saturation if done all at once, and lead to the user developing an intimidation factor and making the GIS software appear even more difficult.

In support of the one day seminar, a book was prepared which presented summary notes related to the theoretical section of the discussed material, as well as a series of articles and journal papers for further reading which were illustrative of the overall utility of GIS in general, and to the SMP. The book was well received by the attendees since it provided them with a good understanding of the concepts of GIS, while also providing plenty of background material for further reading.

For the three day basic introductory and two day advanced courses, separate manuals were prepared for each participant. The intention of the manuals and associated training databases was to provide a mostly stand-alone document which could be used by attendees as a refresher after the course, as well as to allow for self teaching by new CA staff with minimal guidance from former course participants. The reason for this orientation was specifically related to reducing overall training costs.

The course manuals themselves were structured into a series of exercises, seven in each, which focus on the various aspects of the input, storage and retrieval, manipulation and output of data in SPANS. Each exercise has a number of sections as follows:

- background and objective;
- concepts;
- SPANS keywords; and
- procedure.

The background and objective section provides a one to two paragraph discussion of the nature and issues behind the exercise. For example, in the plan input and review exercises, a fictitious person and development proposal (eg.- installing a shore protection structure) was described, and actual MNR work permit forms were enclosed as supporting material. The concepts section presents an overview of the SPANS/GIS principles involved, while the keywords section introduces SPANS terminology as related to the function or feature encountered in the exercise.

The procedure section contains a narrative discussion of the steps involved in accomplishing the goals of the exercises. The intent here was to provide details on the procedures, along with the specific SPANS functions that were to be used. More importantly, the section describes the theory and reasons behind the procedures that were performed, rather than simply indicating which buttons to push. Flow charts accompany each exercise which provide an overview of the procedures and SPANS commands that were used to accomplish the exercise. At the end of most exercises, colour map output has been included which is intended to provide confirmation that the correct result had been obtained.

In the basic introductory course, issues such as operating system details (ie.- related to use of OS/2), and the techniques for working with the presentation manager graphical user interface were discussed at the outset since they are critical to all aspects of the operation of the PC. Other concepts related to hardware and SPANS software specific details were also discussed at the beginning.

Theory as related to the technical aspects of geographic data (eg.- scales, projections) and spatial data processing techniques were interspersed throughout the exercises of both courses at the appropriate places where the concepts were needed. It was felt that this was a more practical approach to introduce this type of material in this fashion, rather than to have one continuous theory session at the beginning.

There were five databases used in the basic introductory and advanced training courses. The first four of these were drawn from the "proof of concept" databases that were created during the user needs study. The fifth and last database was specifically included for the advanced training course.

The name, content and focus of the training databases were as follows:

(1) Regional Shoreline Management (Echo Bay)

This database was created using two 1:20,000 Ontario Basic Mapping (OBM) topographic map sheets, and features detailed wetlands and fisheries thematic layers, as well as recent Ministry of Revenue (MOR) assessment data. The intent of this database was to show the use of SPANS in dealing with wetlands, fisheries and MOR assessment data together for the purposes of environmental impact assessment of potential shoreline development. Sediment survey data (ie.- point data) was added to this database for the advanced course which led to the creation of interpolated surface representations of this data.

(2) Flood Susceptible Shoreline (Sunnyside Beach Road)

The Sunnyside Beach Road area encompasses two 1:2,000 Flood Damage Reduction (FDR) map sheets. Thematic information included detailed shore protection data, contains detailed past applications history; and also recent Ministry of Revenue (MOR) assessment data. This database was specifically used for reviewing proposed shoreline development applications (ie.- plan input and review) and flood warning simulations.

(3) Regional Environmental Assessment - Fisheries (Niagara District Shoreline)

This database was centred on one 1:25,000 National Topographic Series (NTS) map sheet and has detailed substrate and fish habitat data offshore. Onshore, this database contained interpreted landuse mapping from the International Joint Commission (IJC). The applications for this database involved

counting and locating the buildings in erosion prone areas, as well as deriving a map of areas of residential suitability based on landuse, access, proximity to shoreline and shoreline erosion characteristics.

(4) Existing Digital Data Sources - 1:10,000 OBM (Goderich)

There was no SPANS-ready database prepared for the exercise. The data provided consists of five layers from a single OBM map sheet that was obtained from MNR. The focus was on translating data from ARC/INFO format into SPANS format, and creating a complete SPANS database of the OBM layers. This involved some translation of the topologic vectors into SPANS proprietary quadtree format.

(5) Universal Soil Loss Equation Modelling (Kintore)

The area of the database encompasses roughly one 1:50,000 NTS map sheet and contained map layers for each USLE factor, including detailed landuse (land system) mapping. This database was designed to show how the SPANS internal modelling language is used in adapting an existing user defined model. Once the USLE erosion map was produced, the transport capability map was overlayed with this result to produce sediment priority management areas.

Each participant in the either the basic introductory or advanced training courses received their own copy of the manuals, and each CA GIS workstation had a set of the corresponding training databases installed.

4.0 IMPLEMENTATION OF THE TRAINING PROGRAM

The first phase in the implementation of the training program for the CA's was in conducting four one-day orientation seminars, which were held at CA offices in Kingston, London, Exeter and Toronto. Total attendance for these seminars was over 100, and included a broad range of people from technicians to general managers. As mentioned, the content for these seminars included some lecture material on the principles of GIS, but also featured live systems presentations showing a number of successful applications projects. During breaks and at the end of the seminar, hands-on interaction was encouraged on the live systems, even though full-fledged training had not been taken.

The second phase of the training program was in the subsequent offering of the three day basic introductory training program. Eight courses were held at different CA and MNR offices between April 24th and June 21st, 1991. The locations for these courses were Kingston, Port Hope, Exeter, Cambridge, Wroxeter, St. Thomas, Downsview and Toronto. A total of 51 people from the 28 CA's and MNR headquarters participating in the adoption of GIS were trained.

The advanced training course, or third phase of the training program is still being pursued. To date, three courses have been held with a total of 13 participants. The location for these courses were Burlington, Port Hope, and the Geomatics training centre in Guelph. Many of the CA's who have yet to take the course expressed a desire in taking it at a later date since they want to become familiar enough in the functionality of SPANS that was introduced in the basic training course. A number of the early participants in the advance course had applications that they clearly recognized has a requirement for functionality that was not covered in the basic introductory course (eg.- the SPANS modelling language).

5.0 CONCLUSION

The reactions to the various seminars and courses that have been offered has been extremely positive. Through responses and discussions both during and after the courses, the consensus has been that there was a lot of material covered, but there was confidence that the technology was one that could be extremely useful. The fact that the CA's all have training databases and corresponding course manuals on their computers allows for the course attendees to try the exercises again as desired and help to reinforce the learning experience.

The research and information gathered on general computer and map usage provided extremely important background information into the "profile" of the typical user of GIS. This helped to tailor the course material and manual contents appropriate to the course participants. The courses themselves would clearly not have been as successful without this approach.

The value of splitting the training requirements into a series of courses cannot be overstated. The retention of the material after the three day basic introductory course was extremely high, and the confidence levels amongst the participants was correspondingly high. This confidence can be seen in that there are many CA's who are determined at all costs to make SPANS part of their daily operations, and are actively acquiring data and/or contracting out database creation projects.

One issue that became obvious to almost all of the attendees of the basic introductory course was the need for data that pertains to their own shoreline. As a result, many CA's are waiting for federal and provincial digital databases to become available, but are nonetheless very encouraged by the potential of GIS.

A number of CA's have taken the GIS into other programs that they administer by introducing a requirement into contracts for electronic version of map databases in SPANS format. For example, projects such as environmental impacts in the past may or may not have been done in GIS, depending on the consultant that was hired. These projects will act to directly build-up the electronic data for the CA watersheds.

It is interesting to note that since the initial offering of the basic training course, there have been a number of CA people who have taken the course manual and with minimal guidance, trained themselves on SPANS. This indicates that the material has been written in an appropriate fashion for which it was intended.

The basic training and advanced training courses and accompanying manuals have been well received by other organizations besides the CA's. Specifically, organizations such as the Ontario Ministry of the Environment, and Environment Canada have taken the courses with a similar degree of satisfaction. This indicates that the user-focused training databases and manuals are a desired alternative to the functionality driven approach that is currently being offered in GIS software training.

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The need for GIS Spatial Data Servers

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Abstract

Organizations have been investing considerable resources in implementing GIS solutions. With databases becoming available the big challenge now is distributing the data and analytical tools to the users within the organization. With a move towards seamless, continuous databases the file server or local hard disk approaches for handling map sheets are no longer effective. The use of specialized GIS Database servers is emerging as an excellent strategy.

La nécessité de serveurs de données pour les SIG

RÉSUMÉ

Les organisations investissent des ressources considérables dans la mise en oeuvre de solutions faisant appel aux SIG. Avec les bases de données qui deviennent disponibles, le gros défi actuellement consiste à distribuer les données et les outils analytiques aux utilisateurs au sein de l'organisation. Avec la tendance actuelle vers les bases de données transparentes et continues, les serveurs de données utilisés pour traiter les feuilles de carte ne sont plus efficaces. L'utilisation de serveurs de données conçus spécialement pour les SIG s'annonce comme une excellente stratégie.

1.0 Background

Collectively the data and tools used by an individual to solve a particular problem can be thought of as the APPLICATION. The accelerated pace of application development is due to a number of factors; a major one being the increased availability of data.

The emerging reality is that different applications are built on different combinations of data, tools, users and problems. A common view that had initially emerged was that an organization could implement one type of technology to solve all applications. This often meant committing to a particular data format which implies a particular vendor and often a particular computing platform (eg. MS-DOS, UNIX, VMS etc). Application users should not be concerned with how data is stored. The more important question is what can one do with the data.

Another major impediment is the physical distribution of data. How do users running different applications gain simultaneous access to a common organization-wide database? GIS vendors are increasingly relying on networking technology to solve the problem without redesigning their underlying software. The result has been a number of restrictions on application development. Even where one GIS solution is acceptable, network loads coupled with outdated librarian approaches to managing larger and larger spatial databases are getting in the way of application implementation.

We at Digital Resource Systems Limited are faced with the same problem with our PC-based GIS product TerraSoft™ and have been exploring the various options.

2.0 The Problem - Networking with File Servers

With a file server approach the workstation (W/S) is running the GIS application. The file server is merely a disk extension to the work station and 'knows' nothing about the content of the bytes being stored in and retrieved from the files it is serving. The consequence is the workstation must transfer all the bytes from the file server across the network to itself where it can then decide what to do with the bytes.

2.1 Network Traffic

Assume the follow simple case. Data records, in this case sewer lines, all have a fixed length of 100 bytes. The sewer features are kept in the same file with all the other features for a total feature count of 1,000,000 and are accessed with no indexing. If a user wishes to draw the sewer lines lying with the northwest corner of the city then the software task would be something like:

```
Loop:   W/S reads the next 100 bytes from the file server
        W/S checks that the feature is a sewer line
        IF yes W/S checks that the coordinates are within range
        IF yes the feature is drawn
        Goto Loop
```

Because the meaning of the 100 bytes can only be decided by the software that is responsible for the 100 bytes (ie. the workstation), each of the 1,000,000 features (meaning 100,000,000 bytes) must be sent across the network to the workstation. Indexing on coordinates and feature classes will cut down the reads but the implication is same. The indexes are resident on the file server but can only be interpreted by the workstation software.

To avoid this problem some systems have retained the use of a partitioned spatial database. The user at a workstation requests the partition (tile, map sheet, facet, etc) of interest to be loaded down onto the workstation. A GIS librarian books the partition out; when the user is finished, the librarian accepts the updated partition back into the corporate database. This approach, while complicated from the user's standpoint, is satisfactory if the area of interest is confined to one partition. With the recognized need for truly seamless databases partitioning will no longer be an option.

2.2 Supporting Multiple Computing Platforms

Different applications within an organization may best be served using different computing platforms. One user group may find PCs best while another needs UNIX. An unfortunate problem is that just because software from a particular GIS vendor runs on different platforms is no guarantee that DATA is compatible between the different platforms. For example, a SUN RISC running UNIX stores numbers using a different bit pattern than a PC running MS-DOS. The implication is that for data resident on a file server networked to both PC and SUN Workstations, a decision must be made as to whether the data will be stored in PC or UNIX native mode. It is then up to the task running on the particular platform to recognize the difference and make the appropriate conversion - hopefully without the user's involvement.

2.3 Supporting Multiple GIS Environments

Just as it is being acknowledged that an organization needs multiple computing platforms to run a particular GIS, it is also evident there is justification for the use of GIS products from different vendors. Application specific GISs exist for 911, demographic modelling, routing, network analysis, etc. The common ingredient is the database. At present the solution would require the translation of data between the corporate system and the target application systems. Administration of data integrity becomes messy because part of the data responsibility will lie at the corporate level and part will be at the application level. The translation problem is further aggravated when translation requires intermediary formats (eg. DXF, ISIF) rather than native formats. Often translation must be paralleled with processing (eg. topology creation).

2.4 Supporting non-GIS Environments

The consensus is that the GIS database should be a corporate resource accessible by all. A good example is the notification of property owners. It may be desirable to have this performed from a terminal tied to the administration's mainframe system. The software supporting this application would be mainframe-based. The difficulty in solving this task is being able to perform a spatial query: Given a database key that uniquely defines a lot parcel, return the database keys for those parcels lying within 500 feet. How does the mainframe application gain access to this capability? Data translation, resulting in duplicate data sets between the mainframe and the GIS system, has proven to be the most common method.

3.0 The Solution - GIS Spatial Data Server

The solution can be found by looking at the DBMS world - specifically the SQL server technology. This approach is now standardizes the messaging protocol that allows a DBMS server to support client tasks written by different vendors.

This client-server technology can be applied to the GIS world. The file server is replaced by a GIS spatial data server running on a workstation within the network; it could in fact be a task resident on the file server machine. The server continually monitors the network for GIS-type messages. Based on these messages the server sends and receives spatial data.

The server task is the only process that accesses the raw data. It manages all of the relevant indexes including use and update. It provides access based on a user's database privileges. The client knows nothing about how the data is stored and accessed. The storage structure, whether it be quadtree, R-tree, etcetera is irrelevant. The client program is relieved of the burden of data storage and integrity and can concentrate on solving the problem.

3.1 Network Traffic

Network traffic would be reduced substantially. Only needed features or relationships are sent across the network. Re-counting the sewer line scenario: If a user wishes to draw the sewer lines lying with the northwest corner of the city then the software task would be something like:

```
                W/S sends a filter message to Server:
                        ALL  FEATURES  WHERE  FEATURE.CLASS=Sewer
                             AND FEATURE.RANGE IN User.Range
Loop:           W/S reads next message from server
                IF message contains qualifying feature, draw it and repeat loop
```

If there were 200 qualifying features (ie. sewer lines lying in the northwest corner of the city) then only 20000 bytes (plus message overhead) are sent across the network. Contrast with this with file server approach where 100,000,000 bytes were sent to draw the 200 features.

The server utilizes indexes to locate the qualifying features. The client is unaware of any such action - nor does it care.

3.2 Supporting Multiple Computing Platforms

One of the key services that a server must provide is the distribution of data in a format that is native to the client platform. The actual data manipulated by the server would be in the format native to the server.

Network techniques, such as XDR (eXternal Data Representation), can be used to solve this problem. XDR is a communication layer dealing with data representation. Libraries exist on a host of computing platforms that adhere to the XDR model. For example, a UNIX task running on a SUN creates an XDR data representation with a call to an appropriate library function. When the data is received by the MS-DOS client it is interpreted correctly using a parallel MS-DOS XDR library function.

3.3 Supporting Multiple GIS Environments

The GIS application would gain access to the data by using the messaging protocol. If developed in a modular fashion, with data access being a module, the impact on adapting the application to a client-server model would be minimal.

An analogy is the support of different plotters. Typically, plotter drivers are written for each supported plotter and present a common set of functions to the calling program. The calling program has no idea, nor cares, about which driver is installed. It gains plotting functionality by calling a standard set of functions provided by the drivers. The functions within the driver worries about how to command the plotter to perform the required tasks.

3.4 Supporting non-GIS Environments

The use of the server is best described with an example. A clerk wants to do a mailing to all owners of properties lying within 500 feet of a proposed re-zoning application. The mailing application itself is to be done on the adminstration's IBM 4381 mainframe. The GIS data server is running on a SUN UNIX workstation. The 4381 application would request from the user the name of the owner who is applying for the re-zoning. The name is validated in the Property database and the unique key extracted - all by the 4381 application. The 4381 application then starts communications with the GIS server:

Send Open theme message:
GIS_OPEN_THEME PARCELS
Wait for server reply:
SRV_COMPLETE theme description & theme_handle
Send filter message:
GIS_INIT_LIST theme_handle WITHIN 500 OF Parcels KEY="L5678"
Wait for server reply:
SRV_COMPLETE

:Loop

Send request for key of the next polygon meeting the query:
GIS_GET_LIST theme_handle
Wait for server reply:
SRV_COMPLETE polygon key

IF key present add it to temporary table and repeat loop
If key not present terminate loop

Finishes with:

GIS_CLOSE_THEME theme_handle
and waits for final server reply:
SRV_COMPLETE

The temporary table now contains keys for all the affected parcels. The application can then process this table to mail the notifications.

A sample of the analytical functions provided by a server would be:

Message: GIS_OPEN_THEME
Actions: receive theme name
initialize theme internally
set return code
send SVR_COMPLETE message
send theme description (including theme 'handle')

Message: GIS_CLOSE_THEME
Actions: receive theme handle
close theme internally
set return code
send SVR_COMPLETE message

Message: GIS_INIT_LIST
Actions: receive theme handle
receive filter
initialize object/polygon search internally
set return code
send SVR_COMPLETE message

Message: GIS_GET_LIST
Actions: receive theme handle
search for next object/polygon meeting query
set return code
send SVR_COMPLETE message
if object/polygon was found, send it

Examples of query operators:

KEY	=KeyValue
WITHIN	=BufferSize KEY KeyValue
NEIGHBOUR	=KeyValue
THEME	=ThemeName

Examples of filters:

To find all parcels within 100 metres of parcel L5678:
SELECT * FROM THEME PARCELS WHERE WITHIN 100 OF Parcels KEY="L5678"

To find all parcels within 100 metres of sewer pipe #1234:
SELECT * FROM THEME Parcels WHERE WITHIN 100 OF Sewers KEY = "1234"

To find all neighbouring parcels of parcel L5678:
SELECT * FROM THEME Parcels WHERE NEIGHBOUR Parcels KEY="L5678"

4.0 Implementation Issues

GIS spatial data servers will become commonplace when there are sufficient standards defining the two basic issues: services to be provided and the communication protocol. The advantage will be the shift in focus to the application from the storage and retrieval of information.

4.1 Communication Protocol

Of the two issues, communication protocol is the easiest to implement. Here one needs to understand how tasks talk to each other across a network. The International Standards Organization's (ISO) seven-layer Open System Interconnection (OSI) model (Table 1) serves as a basis for understanding the options. Implementation of our TerraSoft™ GIS Spatial server is being done at the highest layer (Application). The advantage is portability; the disadvantage is the increased overhead of sitting on top of 6 other layers. Faster throughput is possible by developing on a lower layer (eg. directly using the Data Link layer) but at the sacrifice of portability.

Table 1. The OSI Model as implemented within SUN

OSI Layer				
7	Application	NFS	TerraSoft™ Server	TerraSoft™ Client
6	Presentation		XDR	
5	Session		RPC	
4	Transport		TCP	UDP
3	Network		IP	
2	Data Link	Ethernet		IEEE 802.2
1	Physical	Ethernet		IEEE 802.3

4.2 Services

Defining what services are needed is difficult because of the lack of agreement on how a GIS should manage data. As the technology matures there comes more consensus. There are two general service levels: relationships and data elements. The relationship level is far easier to deal with because the application is more isolated from the server. In our buffering example, the only thing of interest to the client is the resulting list of database keys. How the buffers were computed, the spatial features interpreted and whether the process was raster or vector-based is irrelevant.

When dealing at the data element level the question of HOW becomes much more important. Issues such as how topology is managed, can a single feature be assigned to multiple feature classes, and are features described with z coordinates all become more critical to the application.

Parallel to the providing of services is the question of how does the server grant permissions. Standard rules on read / write access privileges to data must be established. Should access be regulated on feature class, geographic area and/or related non-spatial attributes?

4.3 Performance Concerns

The major drawback in the client-server approach is increased processing load on the data server machine. With a file server minimal CPU resources are needed to send out the next 100 bytes. With a data server further processing is needed. At the data element level, the effort needed is not large - only the traversal of indexes. At the relationship level, complex geometry tasks of buffer creation and overlay are now added. It is important that a pragmatic division of tasks be made between the server and the client. Simple overlays, such as a single buffer on a set of parcel polygons, would be efficiently done on the server - especially if raster approximations are used. Formal overlaying to produce new themes is a task best left to the workstation client. Clearly the data server needs to be a high performance machine - the new family of RISC machines will be excellent platforms. In the PC world, OS/2 is proving to be a good platform for this type of technology.

5.0 Conclusions

The increased availability of data and recognition of the power of GIS has focused more attention on the development and implementation of applications. There is decreasing interest in the intricacies of how data is collected and stored. There is an increasing demand that data access be public (in a programmatic sense) without the need for translation. This allows users within an organization to select the technology best suited for their task and not be forced into a one vendor solution. The GIS applications in a large organization will vary by data usage, computing platform and end-user skills. The volume of data that must be easily accessed is also becoming a major concern.

An effective approach is through the use of GIS data servers. Fashioned after client-server applications such as SQL servers, this technique allows data to be accessed at both a high level (the relationship) and a low level (the data element). The responsibility for controlling access to the data lies with the server. The client requesting information only receives the information of interest. The filtering of data is done by the server thereby decreasing network traffic significantly.

The major impediment in implementing GIS servers is the lack of existing standards. Presently, the focus on standards has been primarily for the purposes of data exchange. As the technology matures these standards will start to come into play - just as SQL is now an accepted standard.

6.0 Acknowledgements

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Using an Application Programming Interface (API) for Advanced GIS Modelling

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Abstract

With the increasing awareness of GIS comes the need for more applications. GIS vendors have been responding with macro programming languages. Unfortunately these tools provide non-standard languages that are not as powerful, execute slower and have weaker development environments than those offered with mainstream languages such as C. To compensate, users have developed stand alone programs that must import data from the GIS, manipulate it and export the results back to the GIS. An emerging alternative is through the use of an Application Programming Interface (API). APIs are linkable programming libraries based on a standard language like C that offers direct read/write access to the GIS data as well as a set of primitive operators such as point-in-polygon. This approach allows the developer to concentrate on the application, letting the API handle the data storage. The applications solvable in this manner are quite diverse and range from the simple (writing a custom translator) to the complex (interactive optimization for land re-distribution).

RÉSUMÉ

L'utilisation croissante des SIG exige des applications plus poussées dans ce domaine. Les fournisseurs de SIG ont répondu à la demande par des langages de programmation à macro-instructions. Malheureusement, ces outils sont des langages non normalisés qui ne sont pas aussi puissants, s'exécutent plus lentement et offrent un environnement de développement moins performant que les langages courants comme le C. Pour pallier ces inconvénients, les utilisateurs ont mis au point des programmes autonomes qui doivent importer des données du SIG, les manipuler et renvoyer ensuite les résultats au SIG.

Une autre solution est en train de s'implanter : l'utilisation d'une interface de programmation d'applications (IPA). Les IPA sont des bibliothèques de programmations qui peuvent être reliées à un langage courant comme le C et qui offrent la possibilité d'avoir accès directement en lecture et en écriture aux données du SIG et un ensemble d'opérateurs primitifs (par ex. détermination des points dans un polygone). Cette méthode permet au réalisateur de ne pas se soucier de la façon dont les données sont stockées. Tous les outils de l'environnement de développement courant sont utilisables.

1. INTRODUCTION

Geographical Information System technologies have come into wide spread use. Initial installations were in large organizations that typically had as a prime objective data collection, maintenance and reporting. The reporting focused on various cartographic-based styles of map presentation. The result of this pioneering work is an increased awareness of the technology and consequently a demand for not only data but specialized tools for its use.

This demand is best seen by examining the range of specialized GIS programs available. Solutions exist for dispatching, 911 emergency response, route optimization (meter reading to newspaper delivery), demographic analysis supporting market research and even public information systems for bus routing. The author has encountered GIS on trans-Atlantic flights during which the airline used an on-board system to show passengers where the plane was, speed, direction and closest cities.

GISs fall into one of three categories:

1. Broad based to cover many applications (have data handling, basic analysis and usually rich reporting (cartography)
2. Specialized to deal with just one narrow problem; data often collected and pre-processed within broad-based GISs
3. Exploratory, developed within academic circles, to address particular research issues

Why are the broad-based GISs not being widely used in the second and third categories ?

One can speculate on the reasons:

1. Adequate tools not available. Tools that are provided are more along the line of macro languages which are ideally suited for repetition of common tasks relating to overlay, reporting, and topological formation rather than advanced mathematical computation. It is virtually impossible for vendors to add an optimized command to address each and every application that comes along.

2. Too expensive (CPU resources, learning curve and price) to tackle narrow, one-dimensional problems (eg. dispatch system for pizza delivery).

3. Too slow. Even though it may be feasible to tackle a task using a macro language the execution speed may be unacceptable.

An often overlooked avenue is the use of Application Programming Interfaces (APIs). APIs exist in many software domains and are certainly not new to GIS.

2. API DEFINITION

An API is a set of published libraries that can be linked into a user's program to provide

services. The earliest were 'math' libraries; compilers required the inclusion of such libraries before users could compute SINEs and COSINEs. In the case of GIS, the API libraries provide programmatic read and write access to the spatial data, topology traversal and basic spatial operators such as point-in-polygon. Additional services are provided for access to the attribute data, screen input/output and specialized device handling (eg. receiving data from a pointing device and converting real world coordinates).

APIs can be used in three general ways:

1. Accessing the spatial database by a stand-alone program
2. Integrating an application into an existing GIS module
3. Modifying the way in which a particular API library behaves and then relinking the generic software to this library giving the generic software a new capability

2.1 Stand Alone Applications

This is one of the easiest forms of API usage. The most common example is the development of specialized translators. If data existed in some non-standard form for which no translator existed two approaches could be used. Without an API the approach would be to translate the data into some industry standard format (eg. DXF or ISIF) and then translate these into the native GIS format - or vice versa. The API approach would be to develop a program that would read the non-standard data (as in option 1) but create native data using API calls. By using API calls and not trying to decode the vendor's format the programmer's task is made easier and the result is more reliable.

A less common, but effective use, was by a municipality that had maps scanned and vectorized. Although now in the GIS database, the distance annotation was not properly aligned along the associated property lines. To manually edit 20,000 properties was a large task. An API application was written that read just the annotation data and for each annotation a search was done for a property boundary lying within x metres. If such a boundary was found then its angle was computed and the annotation feature set to that angle. The program was simple to write, short and saved considerable operator time.

The developers of specialized GIS applications would be likely candidates for this stand alone direction. Their effort could focus on the application and be free from worrying about how to create, change and access spatial and non-spatial data. Application development would therefore be quicker, cheaper and more reliable. Another important benefit is that by separating the data access component it would be easier to make the application GIS independent.

2.2 From within an existing GIS module

Most GIS products provide a graphic-based environment for performing various levels of real-time analyses. These can range from queries (Show me all the properties sold in

1983) to overlaying (Determine all properties lying within a proposed new zoning area). Often a specialized function is needed within this interactive environment. One such example was developed for facilitating land re-distribution in Spain. The problem is that farm land has been repetitively subdivided over the centuries making effective use almost impossible. A land owner may have title to several hundred properties in a watershed with a total area of just 20 hectares. The solution has been, with consent of land owners, to re-distribute the property into larger holdings such that every one ends up with the same relative value. The solution is non-trivial given all the constraints that must be considered. A simple interactive approach was developed using the API that lets a user establish a target land value, a general confining boundary and then the API application iteratively modifies and overlays different shapes until one is found that satisfies the target. For any given project this simple application saves literally months of analyst time.

This application has been implemented commercially but has caught the interest of the academic community. The Geography Department at the University of Victoria is attempting to further optimize the solution, again using the API as a building block.

2.3 Modifying the API

In this case a user wishes to change the way the standard GIS 'behaves'. This approach can yield great benefits but be very complex to implement. A good example would be to consider the way in which a GIS reads and writes the basic spatial data. Each GIS vendor has developed their own native format - each optimized to meet the goals and objectives of the vendor. The reality for users however maybe that a particular product may have all the analytical capabilities desired but the necessary data is kept in another format. The typical solution would to repetitively translate the data back and forth.

Assuming a programmer knows the format of the data then it would be possible to change the API library component that access the read/write of the spatial elements to recognize not the native format but this alternate data format. This new version can then be linked into the GIS giving the capability of accessing this data without translation.

The challenge stems from correlating the data model between systems. Tradeoffs are typically required thereby curtailing features. An example would be blending a CAD and a GIS. The CAD would provide objects such as ellipses that would not be supported by the GIS (but perhaps approximated). The GIS uses topology which the CAD does not; it may be possible to carry the topology within the GIS format but update problems would occur when the data is modified with the CAD environment.

3.0 USING THE API

APIs can take many forms and be used in many ways. With the advanced development environments available today the problem of testing and using the applications is becoming easier and easier. It does however still require a reasonable knowledge of the programming language - typically C - although many languages are cross-linkable. The programmer must understand the data model within the GIS. This includes how data is grouped and related. Concepts of traversing topology networks and using database keys to relate data tables must all be understood.

A simple example best defines the approach[1]. Consider the basic problem of computing the perimeter of a polygon. The polygon is topologically defined as a set of boundary features each defined by a set of coordinates. The polygon is to be selected by the user interactively within a graphics-based environment.

The problem can be broken down into four basic steps.

3.1 Include the API libraries within the application program:

```
#include <stdio.h>              /*  standard C                                  */
#include <stdlib.h>             /*  standard C                                  */
#include <util.h>               /*  DRS: Utilities (forms, menus, ...)          */
#include <terra.h>              /*  DRS: Map and topology definition/access     */
#include <fterra3.h>            /*  DRS: Graphics environment                   */

/*   global variables used by the API in the Graphics environment              */
extern GisThemeType   GisTheme;
extern boolean        GisThemeOpen;
```

3.2 Ask the user to select the polygon:

```
/*   'Message' displays a message on line n of the dialogue area               */
Message(1,REPLACE,"Export lot boundary coordinates for which property?");
Message(2,REPLACE,"   (Enter point within desired property)");

/*  The API Point routine returns a real world coordinate set along           */
/*    with the button type;  the latter is in PtType.  In this example        */
/*    the loop is repeated until PtType = GOOD.  An important plus            */
/*    of using Point is that all conversion to real world is handled          */
/*    along with access for the user to all windowing ftns (eg. zoom)         */
do
    {
    Point(&x,&y,&z,&PtType);
    } while (!InSet(PtType,GOOD,ABORT,ENDSET));
if (InSet(PtType,ABORT,ENDSET))
    return(0);
```

3.3 Determine which polygon has been selected:

```
if (!VecFindPoly(&CadFile,&GisTheme.VPolyFile,x,y,&VPolyHandle))
    {
    Message(1,WAIT,"Lot not found");
    return(0);
    }
```

---

[1]The API example is based on TerraSoft™ - a GIS product developed by Digital Resource Systems Limited. All API calls are shown as **BOLD COURIER OBLIQUE**. The API also provides some global data structures which are shown as **BOLD COURIER**.

3.4 And finally compute the perimeter:

```
/*  initialize perimeter to zero                                    */
Perimeter=0;

/*  Walk through each segment of each feature                       */
/*  VPoly.NumLinks details number of features defining boundary     */
for (i=0; i<VPoly.NumLinks; i++)
        {
        /*  Load ith feature in theme called GisTheme               */
        GetObject(&CadFile,GisTheme.VPolyFile.Link[i].LinkHandle);

        /*  Line.NumPoints defines number of points in current feature  */
        for (j=0; j<Line.NumPoints; j++)
                {
                /*   The coordinate pairs are in Line.Coords[j]     */
                Perimeter=sqrt(sqr(Line.Coords[j].X-Line.Coords[j+1].X)+
                        sqr(Line.Coords[j].Y-Line.Coords[j+1].Y));
                }
        }
```

4. PROBLEMS WITH THE API APPROACH

The API approach requires a greater level of programming skill than just using the macro programming languages provided with most GIS products. This in the past has confined the use of the API to large organizations that could justify having the necessary resources. Although programming environments have become far easier and more productive the effort is still not trivial.

A second concern is that changes made to the API by the vendor may result in needed changes in the API-based software. This problem is present to varying degrees with all software upgrades. However the effort at the C-programming level will be higher.

A third concern is because of the relatively low use of APIs, the level of API sophistication can likely be improved. APIs are typically used by the vendors themselves to develop the core product. Hence the API is optimized for the vendor's use and not for the typical end-user. As more end-users become API users there will be a change in outlook by the vendors.

5. FUTURE DIRECTIONS

The use of APIs will become easier as the software tools become more powerful. An exciting example is in the PC world. The Microsoft Windows environment allows for communication between window applications through a technique called DDE (dynamic data exchange). The API in this environment would become a server program that would be responding to messages from client applications rather than linking in C code.

Many programs are becoming DDE-aware including spreadsheets, database and development

products such as Visual Basic[2]. This would for example allow a database program to request from the user a owner's name and a buffer distance. The DBMS application would validate the owner name and determine the unique identifier for the property(s) that the owner owns. A DDE message would be sent to the API server application requesting a list of all property identifiers lying with the buffer distance of the target property identifier. This would all be done without one line of C programming code.

Approaches such as DDE would not replace using a language such as C as the latter still would offer greater flexibility and speed.

6. CONCLUSIONS

The growing demand for GIS applications is outstripping the ability of GIS vendors to respond with off-the-shelf solutions. The typical macro langauge capabilities are too weak. An alternate solution is the use of linkable libraries useable by languages such as C. These APIs provide services to programmers for accessing the data, traversing topology and performing basic spatial operations. This relieves the programmer of these often difficult tasks. This capability allows for the development of solutions that are optimized for the specific application while retaining the benefit of a generic GIS (ie. data maintenance and basic reporting and analysis). Although currently confined to use by experienced programmers, the rapidly improving computing environments will make this capability more accessible.

[2]Visual Basic is a product developed and sold by Microsoft Corporation.

DATACASTING OF GEOMATICS INFORMATION

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ABSTRACT

Datacasting is the use of electronic means to make data broadly available to geographically dispersed sites at the same time. The transmission can use a full communication channel on any frequency band, a satellite transmission or an ancillary signal which is transmitted as part of a radio or television broadcast. Datacasting of geomatics information is desirable when the information can be used by a large geographically dispersed audience. However, datacasting channels usually have a very limited capacity. Therefore, geomatics information needs to be communicated using compression algorithms and error correction techniques to ensure the data is received correctly. This paper describes some potential applications for datacasting of geomatics information, some alternative methods of datacasting, and looks at various graphics communication protocols which could be used.

DIFFUSION DES DONNÉES DE GÉOMATIQUE

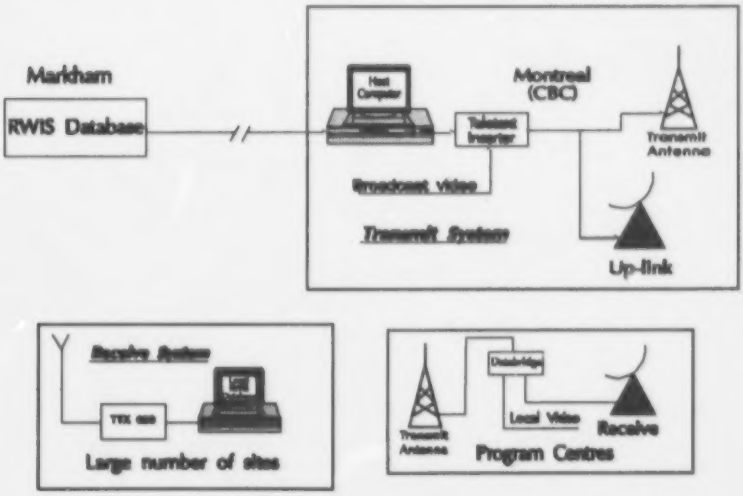
RÉSUMÉ

La diffusion des données est l'utilisation de moyens électroniques pour diffuser simultanément des données dans de nombreux endroits géographiquement isolés. La transmission peut se faire par un canal de télécommunication complet sur toute bande de fréquence, par une liaison satellite ou par un signal auxiliaire transmis dans le cadre d'une émission de radio ou de télévision. Il est souhaitable de diffuser des données de géomatique lorsque l'information peut atteindre un vaste auditoire dispersé géographiquement. Toutefois, les canaux de diffusion ont normalement une capacité très limité. Ainsi, il faut communiquer les données de géomatique au moyen d'algorithmes de compression et de techniques de correction des erreurs pour s'assurer que les données sont bien reçues. Le présent article décrit quelques applications potentielles de la diffusion des données de géomatique, d'autres méthodes de diffusion et divers protocoles de communication graphique qui pourraient être utilisés.

TYPICAL APPLICATIONS

The following are some typical applications which benefit from the datacasting of geomatics information.

An example of a government geomatics information service is the Road Weather Information System (RWIS) operated by the Ministry of Transportation of Ontario. This service provides up to date road and weather conditions throughout the Province of Ontario. Much of the information is presented in a graphical format such as the weather maps, radar imagery etc. It is used by road maintenance centres to determine, amongst other things, when to plough the roads. However, the same data is also used by radio and television stations to provide listeners and viewers with up-to-date road and weather reports. Until now, the RWIS has been available to the road maintenance centres via dial-up and leased lines. However, because of the high telecommunication costs, only approximately 20 of the 350 road maintenance centres in Ontario have access to the RWIS service.



Ontario Datacasting Trial

Figure 1

A datacasting trial is now being conducted to determine if the RWIS data can be delivered to all 350 road maintenance sites via the ancillary channel of a CBC television broadcast signal. As can be seen from Figure 1, the data is inserted at the head-end of the television transmission. From that point on, the distribution costs remain constant no matter how many receive sites are added. If this trial is successful, then all the road maintenance centres will receive RWIS data via a television signal. Of course, once the data is broadcast, it is also available to any member of the general public who has a micro-computer and the appropriate (low cost) receive equipment.

Fishermen are already being aided by electronic maps and charts. Some of the geomatics information required by fishing boats and other vessels could be datacast to make optimum use of the communication channels available. For example, weather, ice conditions and notices to seamen are required by most vessels and could be datacast on a continuous or scheduled basis. Successful experiments have already been carried out on the communication of sea surface temperature charts to ships at sea using advanced graphics communication protocols and HF radio.

DATACASTING ALTERNATIVES

The principal reason for the use of datacasting is the need to send the same data to a large number of sites on a regular basis. Therefore, operations which have many regional offices or organizations with a geographically dispersed client base are ideal candidates for such services.

Satellite signal coverage is normally a very large geographic area. While satellite systems are ideal for datacasting applications, the cost and complexity makes consideration of other alternatives such as spare capacity of TV and FM broadcast channels and even specially assigned frequencies desirable.

Ancillary Channel of a Television Broadcast

Data communication signals can be carried in the Vertical Blanking Interval[1] (VBI) of a television broadcast without any adverse effect on television reception. The extra data communication signals are generally known as teletext.

[1] In North America, the 525-line 60 fields-per-second television signal includes a VBI of 21 lines to allow the receiver to synchronize and perform vertical retrace before the active video picture begins. This period can be viewed if the vertical hold is purposely misadjusted.

Teletext permits the transmission of data from one point to many points located within a broadcaster's range. Currently, 4 lines of the VBI are used for teletext transmissions which equates to a rate of approximately 50 kbits/sec. In the case of broadcasters such as CTV and CBC, coverage can include almost the whole country.

To put this in perspective, the power of teletext transmissions are such that the entire text of a typical newspaper could be sent to over 99% of the population of Canada in a little under 3 minutes. This could be compared to a 1200 baud telephone line which would take approximately 130 minutes for one transmission of the same information and would completely jam the telephone network to try and route this information into all the homes.

Since the teletext signal piggy backs on a television signal which already reaches a large geographic area, it provides an economic and reliable alternative to other means of communicating substantial amounts of data to large audiences.

As can be seen in Figure 1, the reception of teletext requires a television antenna or a connection to the cable network, a teletext modem which is connected to the RS-232 port of a micro-computer and some software which processes the received data. The teletext modem costs around $650. This price will probably reduce for volume productions.

FM Sub Carriers or SCMO[2]

There are approximately 350 FM radio stations in Canada, most of which do not use SCMO for data transmission. However, SCMO technology is well proven and is being used for the local distribution of financial information in several cities in North America.

The SCMO broadcast is effective within an area slightly smaller than that covered by the station's main signal. This means approximately a 60 Km radius from the antenna in most cases. The most common data rates for SCMO broadcasts are 4800 and 9600 baud.

Most FM transmissions are local in nature, with very few being networked into larger geographic areas. Therefore, SCMO is primarily used for local data distribution purposes but could be used on a national basis if a national network was available.

---

2. Subcarriers of a FM station which can be used for data transmission without affecting the normal FM radio broadcast are known in Canada as the Subsidiary Communications Multiplex Operation, in the US as the Subsidiary Communications Authority and everywhere as the FM sub-carrier.

VSAT

Large corporations have already found VSAT (Very Small Aperture Satellite Terminals) networks to be very cost effective in comparison to leased lines or microwave networks particularly when the distances are large. The data needs only to be organized and transmitted and there is no complicated switching or multiplexing. There are already thousands of VSATs in use across North America. While some of these are used for two way communications, many are one way communication systems. In Canada, the ANIKOM series of VSAT services offered by Telesat Canada are being used extensively.

There are some limitations on the placement of satellite terminals. The antenna must have a clear view of the satellite. This can be a serious limitation in cities where there are many tall buildings.

COST COMPARISON

Teletext and SCMO services enjoy only a limited use in Canada and, therefore, accurate operational costs are not readily available. The comparison in this paper is based on the limited experience available in Canada and, on data published on operations in other countries. Costs may vary from application to application. For example, the cost of a teletext transmission may be lower if the time of delivery is relatively flexible in comparison to a transmission which must adhere to a tight schedule.

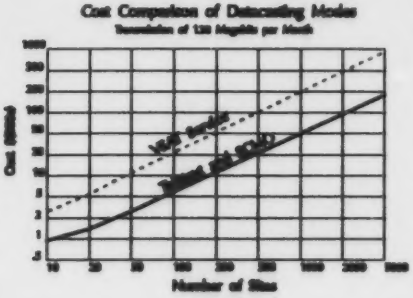


FIGURE 2

The graph in Figure 2 (which is a log/log scale) shows the comparison of costs for the three different modes of transmission of 16 megabytes of data per month. It will be noted that teletext and SCMO costs are approximately 1/6th the cost of VSAT transmissions.

The costs used to for the graph were broken down into two basic categories: head-end costs and receive site costs. The head-end costs are constant no matter how many receive sites are established. The head-end cost for a VSAT service would be approximately $1,800/month for a 300 baud service available 24 hour a day, seven days per week. A higher speed VSAT circuit would be considerably

more expensive. For teletext and SCMO, the head-end costs have been estimated to be $400 and $200/month respectively. The reason for the much lower cost is that the signals are being sent on a network that is already in place for other purposes. The total receive site cost is directly proportional to the number of receive sites installed. For the VSAT service, it is estimated that the capital cost, installation and maintenance amortized over a five year period would be approximately $188/month. For teletext and SCMO terminals, the cost is estimated to be in the range of $30 to $40/month.

ERROR PROTECTION

Since datacasting is a one way transmission, it is very important that steps be taken to ensure the data integrity at the receive sites. Clearly, Forward Error Correction (FEC) schemes must be used in order to both ensure the integrity of the received data and to enable correction of errors.

FEC for Teletext

The FEC scheme for teletext needs special consideration. As well as accounting for errors which can cause loss of a one or two bytes of data, the FEC must allow for some errors which may cause the loss of a complete VBI line of data.

Measurements of the teletext reception on a television channel range from bit error rates of 10^{-8} or better in areas of good signal reception down to 10^{-3} where TV reception is poor. Most of the errors detected tend to be one or two bit errors on a VBI line. In most cases where error rates are high, the reception can be improved by using a better antenna.

The FEC scheme chosen for teletext uses a modified Reed-Solomon (RS) code. This FEC scheme is capable of correcting any one byte or one or two bit errors on a single VBI line and of replacing one or two VBI lines lost in each bundle of 16 lines. It will also detect most possible errors in teletext transmissions. This FEC scheme is, therefore, extremely powerful and ensures the integrity of teletext receptions over a wide range of signal reception conditions.

Recent tests carried out simultaneously at different locations indicate that when errors do occur they are very likely to occur at all sites at the same time. This indicates that many errors are probably caused by imperfect switching and other interference in the TV network. Therefore, monitoring of reception at key sites would allow for detection of most errors and therefore easy correction by retransmissions.

FEC for VSAT and SCMO

Error rates with SCMO are claimed to be as low as 10^{-6}. However, multipath and other factors have a tendency to reduce this, particularly for mobile applications. Therefore, it is important that the appropriate FEC schemes are used to ensure data integrity.

Error rates for VSAT transmissions depend on a number of factors including the size of the dishes used, the power of the satellite transmissions and the position of the satellite in relation to the receive site. These and other factors are taken into account in choosing the appropriate FEC scheme.

VSAT and SCMO are continuous transmissions and therefore not subject to special treatment as is the case with teletext. Therefore, more conventional FEC schemes can be used such as convolutional codes and RS block codes. A variety of these codes are used depending on the degree of data integrity required in the received signal.

GRAPHIC COMMUNICATION PROTOCOLS

Comparison of Graphic Communication Protocols

The following is a description and a comparison of four graphic communication protocols and their suitability for datacasting applications. The choice of a protocol will depend on several factors including the nature of the information to be transmitted, the importance attached to the cost of each transmission and the equipment available at the send and receive sites. Protocols used should also adhere to the principles of open systems interconnection (OSI) established by the International Standards Organization. This will facilitate the communication of graphical information into other networks and will ensure independence from particular hardware or display technologies.

Facsimile

Facsimile machines are in wide spread use and are likely to be even more so in future years. Facsimile machines which fit into a briefcase or can be installed in a car are already available and cards for personal computers are available which display the facsimile received directly on the computer screen.

Facsimile provides for the communication of documents by transmitting one spot of the document at a time. Transmission errors, which cause a few spots to be in error, are, therefore, not usually significant and can be tolerated. Only minimal forward error correction is required. The disadvantage of facsimile is

the amount of data that needs to be sent for each page of a document and the resulting long transmission times and significant costs if several pages are sent. The format of the documents that can be sent by facsimile is also limited. To cut a map into letter size sheets, send it by facsimile and then try to piece it together the other end is far from satisfactory.

A typical letter size page sent by a CCITT Group 3 facsimile transmission would require approximately 60 Kbytes of information to be transmitted. At a transmission rate of 2400 baud, this would require approximately 3.3 minutes of a data channel.

Despite the drawbacks in using facsimile communications, it will probably find widespread use because of the installed base of machines in offices and its convenience for a variety of applications.

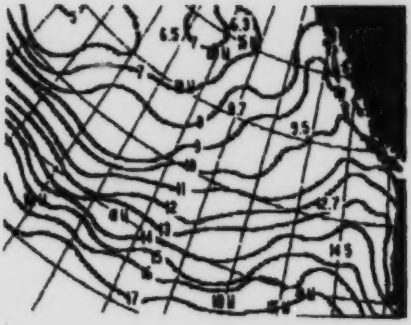
NAPLPS

Some years ago, the potential importance of easy to use information services for home and business applications was recognised and standards were developed which permitted the communication of text and graphics in a device independent manner. The standard developed in North America was the North American Presentation Level Protocol Syntax (NAPLPS) which describes a specific data syntax, at the OSI presentation layer, for the efficient communication of text and graphics. For many applications, this protocol is ideal and is the one used for the Road Weather Information System in Ontario.

NAPLPS permits an image to be represented by geometric elements: point; line; arc; rectangle; and polygon; and coordinates which represent the position of these elements on a unit screen. To this is added attributes for each element such as colour, texture etc. This is a very efficient and effective manner of representing an image and results in a very small number of bytes being communicated in the majority of cases.

NAPLPS requires some processing of the data at the receive site to translate the data received to an image on the screen. This can be accomplished with circuitry dedicated to the task of decoding the NAPLPS protocol or by software in a small micro-computer.

The image shown in Figure 3 can be represented with 2620 bytes using the NAPLPS coding scheme. Allowing a very generous 100% overhead for the forward error correction coding, this would take approximately 17 seconds to transmit over a 2400 baud channel. This is less than 1/10 the cost of a facsimile transmission of the same information and, therefore, schemes such as NAPLPS are likely to find widespread use.



SEA SURFACE TEMPERATURE

FIGURE 3

Computer Graphics Metafile

The Computer Graphics Metafile (CGM) provides for the description, storage and communication of graphical information. It is a recognised international standard (ISO 8632) which was established to permit the exchange of files between systems running computer graphics applications such as the Graphics Kernel System. Like the NAPLPS standard, it is based on graphical primitive and attribute elements. However, it is more comprehensive and, therefore, more complex than the NAPLPS standard. It would be suitable for applications which require complex processing of the graphics data at the receive site. This is most likely to be the case when scientific surveys or similar activities are involved.

The number of bytes required to represent an image depends on its complexity. For relatively simple images, CGM would require between 1.5 to 3 times the amount of data than for the NAPLPS coding scheme. For more complex images, CGM would require less data than NAPLPS.

MACDIF

There has been considerable work in Canada over the last few years on the development of a Map And Chart Data Interchange Format (MACDIF). The effort to develop MACDIF is being carried out cooperatively by several Federal Departments, in particular, the Canadian Hydrographic Service, the Department of Energy, Mines and Resources, the Department of National Defence, the National Archives of Canada and the Department of Communications. The Ontario Ministry of Natural Resources and the American Federal Government National Atmospheric and Ocean Service have also supported this work. The Ontario Ministry of Natural Resources has specified a profile of MACDIF called MDIF for mapping purposes used by the province. Proposals to standards setting bodies, such as the International Hydrographic

Organization, have also been made which may result in an international standard being issued.

A map or chart is a highly structured description of a geographical area. It is much more than an image of the area it represents. A map consists of features such as lakes, rivers and roads which not only have a geographical boundary but also have a large number of other attributes. There can be a large number of features used in a map and the volume of data required to describe a map can be very large. However, since maps and charts do not often change, it will be a rare occurrence that these will be communicated in their entirety. This basic map data would then be complemented with such things as weather overlays. The weather overlay would be coded with MACDIF so that it can be represented with a minimum number of bytes and, therefore, data communication would be kept to an absolute minimum, not only decreasing communication costs but also improving efficiency of the operation.

MACDIF can be used to communicate anything from raw digitized map information to a fully symbolized and cartographically enhanced map or chart. MACDIF organizes information into a number of categories which define the overall structure of the map, its relation to a world coordinate system and features that make up the map, their attributes and boundaries, and optionally, any related symbolization and topographical relationships. The data syntax for describing the graphical elements is similar to that of NAPLPS. However, it provides some special structures for reducing the amount of data required for cartographic features.

The overall map or chart structure is defined as a syntactic hierarchical tree where each section is broken into sub-sections and sub-sub-sections down to the data element.

The amount of data required to represent a map such as that shown in Figure 3 would be much the same as that required for the NAPLPS coding scheme. However, since it is likely that the basic map would already be on board before the ship leaves port, only the temperature information would need to be sent and overlaid onto the map. This would reduce the amount of data required to be sent to about 500 bytes. Allowing a generous 100% overhead for the FEC, this would take approximately 3.3 seconds of channel time.

While the sending of overlays is possible with both NAPLPS and CGM, it is easier to accomplish with MACDIF for maps and charts because the data is referenced to a world coordinate system.

When the cost of sending information using the MACDIF coding scheme is compared to that for NAPLPS, CGM or Facsimile, it can be seen that there can

be considerable cost and operational advantages. The processing of the data at the receive site can easily be accomplished with software in a portable personal computer and, therefore, if any significant amount of data is to be transmitted, the extra cost of the computer and software would be recovered in a very short period. The use of MACDIF and similar protocols could, therefore, make many more applications economically viable than would otherwise be the case.

CONCLUSIONS

This paper has explored some of the potential applications for datacasting of geomatics information, some which are now in a trial phase. Although satellite transmissions do offer a very effective datacasting service, the cost and complexity makes it worthwhile exploring other alternatives such as SCMO and teletext. As has been shown, both SCMO and teletext can provide effective datacasting services for approximately 1/6th the cost of VSAT service. This paper has also reviewed some graphic communication protocols. Since datacasting channels often only have a limited capacity, it is important that efficient graphics communication protocols be used so that the minimum amount of data is transmitted. The use of protocols which describe an image by geographical elements can result in enormous reductions in channel time with resulting savings in cost. For example, a page transmitted via facsimile would take approximately 3.3 minutes to transmit at 2400 baud. Similar information sent using the MACDIF coding scheme could be transmitted in 3.3 seconds or 1/60 of the time. The use of coding schemes such as MACDIF or NAPLPS will require a greater amount of data processing at both the send and receive sites. However, this data processing can be accomplished with micro-computers, the cost of which would be more than offset by the savings in communication costs and improvements in operational efficiency.

The choice of a graphic communications protocol will depend on the needs of the application. It can be clearly seen that use of protocols which describe images by geometric elements will make many more datacasting applications economically viable.

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A Graphical Query System for Index Information on Published GSC Maps

by
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The GSC Map Information System (GMIS) was developed to provide a query system for index information on over 16000 maps published by the Geological Survey of Canada. The system allows the user to point to any location in Canada and retrieve index information on the maps covering that point. The user may select the index data based on map series, title, authors, and scale. The system is completely bilingual as well as mouse driven and menu-based in order to provide a user-friendly interface for members of the public as well as for GSC staff.

The software runs in an X Windows environment on SUN Sparcstations and in a VMS environment on the GSC VAX 8800 and it makes use of the Geographic Information System Arc/Info. The Arc/Info database is also being used to produce high quality index maps for publication. The digital base maps of Canada were provided by the National Atlas Information System of the Surveys, Mapping, and Remote Sensing Sector of EMR and the attribute data for the GSC maps were provided by GEOSCAN.

Système d'interrogation graphique pour obtenir de l'information sur les index des cartes publiées par la Commission géologique du Canada

RÉSUMÉ

Le Système d'information cartographique de la Commission géologique du Canada fait office de système d'interrogation graphique pour l'obtention d'information sur les index de plus de 16 000 cartes publiées par la Commission géologique du Canada. Le système permet à l'utilisateur d'obtenir de l'information sur les index des cartes portant sur n'importe quel endroit au Canada. L'utilisateur peut choisir les données d'index à partir de la série, du titre, des auteurs et de l'échelle des cartes. Le système est entièrement bilingue et il est commandé par la souris et par des menus; l'interface est donc conviviale et peut être utilisée autant par le public que par le personnel de la Commission.

Le logiciel tourne dans un environnement X Windows sur des SUN Sparestations et dans un système d'exploitation à mémoire virtuelle sur le VAX 8800 de la Commission; il peut par ailleurs utiliser le logiciel de système d'information géographique Arc/Info. La base de données Arc/Info est également utilisée pour produire des cartes-index de haute qualité à des fins de publication. Les cartes de base numérisées du Canada ont été fournies par le Système d'information de l'Atlas national du Secteur des levés, de la cartographie et de la télédétection d'EMR et les données d'attribut pour les cartes de la Commission ont été obtenues de GEOSCAN.

DESIGN OF A SYSTEM OF METADATA FOR THE CANADA SOIL INFORMATION SYSTEM (CanSIS)

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ABSTRACT

The Canada Soil Information System has in operation a system where meta data is integrated into the creation, update and storage of its data sets. Meta data describes information about the data sets such as theme, title, source, author, method of collection, scale, stage of development, lineage and positional accuracy. Stage of development describes the dates the data set was digitized, edited and linked to its data base. Meta data is constantly maintained because it is created and updated at the same time and in the same workspace as the data sets. There are over 1800 data sets in CanSIS: they have different scales, themes and database structures. The meta data is kept on disk to allow on-line query of all the data sets but only the active Data Sets are kept on disk: in this way a large number of data sets can be maintained with a minimum of disk space. All the data sets are maintained on two sets of tapes (for safety) with one suite of software for creation, update, storage, retrieval and query. With appropriate standards, the close coupling of data sets and meta data could be used to develop a National Directory of Data Sets.

SYSTÈME DE MÉTADONNÉES INTÉGRÉ AU SYSTÈME D'INFORMATION SUR LES SOLS DU CANADA (CanSIS)

RÉSUMÉ

Le Système d'information sur les sols du Canada (SISC) intègre un système de métadonnées qui sert à la création, à la mise à jour et au stockage des fichiers. Les métadonnées fournissent des renseignements sur les fichiers comme : thème, nom, source, auteur, méthode de collecte, échelle, stade d'élaboration, lien et précision de la position géographique. La rubrique "stade d'élaboration" donne les dates où les fichiers ont été numérisés, mis en forme et enregistrés dans leur base de données. Les métadonnées sont toujours à jour étant donné qu'elles sont créées et mises à jour au même moment que les fichiers et rangées au même endroit. Le SISC comporte plus de 1 800 fichiers, dont l'échelle, les thèmes et les structures de base de données diffèrent. Les métadonnées sont sur disque pour permettre une interrogation en direct de tous les fichiers, mais seuls les fichiers utilisés sont ainsi conservés. De cette façon, on peut disposer d'un grand nombre de fichiers dans un espace disque minimal. On conserve deux copies de sauvegarde sur bande (pour des raisons de sécurité), et un ensemble de logiciel sert à la création, à la mise à jour, au stockage, à l'extraction et à l'interrogation. En se servant de normes appropriées, les fichiers et les métadonnées conjugués pourraient servir à la préparation d'un répertoire national des ensembles de données.

INTRODUCTION

This paper describes the development of the meta data system in the CanSIS Program. CanSIS is the Canada Soil Information System; it is a program of the Centre for Land and Biological Resources Research, within Agriculture Canada. For 20 years, CanSIS has had a system for creating and updating spatially referenced data sets that describe soil. A data set is the collection of spatial themes and the associated attribute data that describes a defined area of the earth. Soil and hydrography are examples of spatial themes. For the 20 years, the archive that stores the data sets and the meta data that describe them have been continuously maintained.

The experience is discussed under the main headings of the primary system, the meta data system, the system operation, the historical development and the present situation. The theme expressed is the growing interdependence of the meta data system and the primary system. The last section relates meta data to a directory of data sets.

PRIMARY SYSTEM

The primary system creates, updates and stores data sets; it allows a large and varied number of data sets to be maintained on a minimum of disk space. There are over 1800 data sets currently stored in the system; there are three different models of soil themes: the Soil Map of Canada which is one data set at a scale of 1:5 million, the Soil Landscapes of Canada which consists of 14 data sets at scales of 1:1 million and the detail soil maps which consist of 1700 data sets at scales ranging from 1:10,000 to 1:125,000. Each model has its own attribute data base design. The data sets have overlapping geographical extents; for example the Soil Landscape Map of Southern Ontario overlaps with the hundreds of detail maps of Southern Ontario.

META DATA SYSTEM

The meta data system creates, updates and stores the data that describe the data sets. (APPENDIX A provides an example of meta data text and APPENDIX B describes the meta data, data base of the CanSIS Program.) The meta data provide the following:

- a description of the scientific theory of the soil survey
- the authors and contributors
- key stages of the production of the data set including :
  - the stage of linkage with the soil names and layers data base
  - the date digitising was started for each theme, and for each theme, the date that various edits were performed
- planimetric parameters such as projection, UTM zone and datum (NAD27, NAD83 or ATS77),
- the external agencies to which the data sets were exported, the date and the format it was sent and the contact person in the external agency

SYSTEM OPERATION

The meta data system cannot function independently of the primary system because the meta data cannot be created, updated and stored independently of the data sets. An examination of the primary and meta data systems, shows that they must be integrated to recognise the inherent link between the data upon which they operate.

In the primary system, data sets are stored on tape, they are restored to disk for update and analysis, backed up to tape and then they are deleted from disk. It is only when they are on disk, that the meta data system can access the data sets. The data sets are backed up to two tapes; even if one tape is in error the data sets can be restored from the second tape. The catalogue of data sets and the meta data are constantly maintained on disk.

When the data sets are restored to disk, they are put in directories that are separate from the meta data. It is awkward to refer to, or update the meta data from within the directory of a data set. The Historical Development section first presents the solution that was finally implemented and then describes the problem in storing the meta data only once.

In the final implementation, the meta data are updated in the workspace of the data sets but they are accessed for management reports and queries from a separate directory. There is an audit trail that gives each version of the data set and the corresponding meta data. At present, not all data sets have meta data but meta data are being added faster than the data sets.

HISTORICAL DEVELOPMENT

The orginal primary system was a custom written system developed in 1971. There was also a meta data system. In 1987, the primary system was converted to a commercial system. The commercial system created the need for meta data with greater detail and structure but the system that was developed made it difficult to establish responsibility for the completeness and accuracy of the meta data. The meta data system was modified to make the users that updated the data sets responsible for also updating the meta data.

The Original System

Starting in 1971, the primary system was a custom written system built on IBM mainframe technology; the digital maps were stored on tape and catalogued; retrieval to disk was brief - no more than half an hour to allow the maps to be updated and for plots to be made - then after their moment in the sun, the maps were put back on tape. The meta data system consisted of the catalogue and a separately maintained data base of activities performed on each data set which was maintained for costing. But the meta data were incomplete because it was not important enough to be maintained: its purpose was to provide month and year end reports on the cost of making maps. Even if the data base of activities was not well maintained, the quality and accuarcy of the data sets and more importantly the plots of the soil maps were just as good. There was little need to describe the data sets: all the data sets were maintained in table coordinates so it was not important to store the map projection, the soil maps were printed by photomechanically overlaying them with base maps so the exact alignment with the base was not measured or recorded, all data sets had only a soil theme so there wasn't much point in recording the themes and since the attributes consisted of a single 60 byte character field which was not checked against the data base of soil names and layers, the linkages with other data bases were not recorded. However what was maintained correctly was the catalogue of data sets because the primary system would not function without it. When the commercial system was purchased, there was a big expectation that there would be an up-to-date and accurate catalogue of all the data sets.

Requirements for Meta Data

In 1987, ARC/Info was the commercial system that was purchased; during the next two years, a thousand digital soil maps were converted from the custom system to ARC/Info. With the move to a commercial system came the need for more and better meta data. The most obvious need was to know what data sets had been converted and their stage of completion. It was important to know what maps were transformed from table coordinates to earth coordinates and what were the map projections. The commercial software now permitted the soil attributes associated with a polygon to be linked with the data base of soil names and layers: there was the need to know what data sets had been linked. The commercial software also permited the transfer of data sets from and to other agencies where no transfer had been possible before. This transfer created the need to describe the content, lineage and quality of the data; and what data had been distributed, to who and in what format. With greater interest in transfering data was the need to report holdings of digital data sets to inter-agency committees. Finally the greater complexity of the data sets created the need to record the themes of the data sets.

Design of the Primary System

The primary system that was developed was similar to the custom written system: the differences were that the commercial package was used to manipulate the data sets and the data sets would stay on the disk for several weeks. Workspaces were created on disk; data sets were created in the workspaces and then they were backed up to tape and deleted from disk; custom written software was developed to maintain a catalogue of the datasets on tape.

Design of the Meta Data System

The meta data are stored twice: once in a central directory and again in the workspace of each data set. The central directory contains an online data base of all the data sets and a directory with one text file for each data set. The workspace contains a miniature data base and a text file of its data set.

When a data set is restored to disk, a computer routine moves a complete copy of the meta data for that data set from the central directory to the workspace. The user updates the data set and updates the meta data within the workspace. When the data set is backed up to tape, a computer routine copies the meta data from the workspace back to the central directory.

This system clarifies responsibility for updating the meta data because it forces the user to update the meta data at the same time as the data set. The meta data in the central directory are protected against direct update, they must be updated from the meta data within the workspace. When the meta data and the data set are in the same workspace it is easy to refer to them both at the same time. The system provides an audit trail of meta data: versions of meta data can be traced by restoring versions of the data set from tape to disk.

The Problem of Storing the Meta Data only once

The first system that was developed after the installation of the commercial software, stored the meta data only once in the central directory and this fact created problems for the creation and update of the meta data. This problem was not immediately obvious because the meta data is made of three parts: the first and second parts are ideally suited to be maintained in the central directory but the third part needs to updated in the workspace of its data set. The first part is a fixed length file called the JOBID FILE; it is created once by the supervisor of the National Soil Data Base program and not updated afterwards. The second part consists of one fixed length file called the Attribute Linkage Status File and the text file. The second part can be updated in an account separate from the workspace because it describes data that is not contained in the data sets: The third part consists of four fixed length files: the JOBID STATUS FILE, the NSDB COVERAGE STATUS FILE, the ACTIVITY LOG and the DATA TRANSFER FILE. These four files describe data that are in the data sets and their separation from the data set at the time of update was a source of error:

- it was awkward to update the meta data from within the workspace
- it was easy to forget to update the meta data because it could be updated any time but once the data set had been backed up to tape, it was no longer available
- it was hard to establish responsibility for the completeness and accuracy of the meta data because everybody had access to it

PRESENT SITUATION

At present, specially trained users restore data sets from tape and run a program to bring a copy of the meta data into the workspace; then they update the meta data and backup the data sets to tape. This gradual approach has allowed interested users to enter important meta data and gain

understanding of the system while allowing most users to do their work without being affected by changing procedures. The specially trained users are adding meta data faster than all users are adding data sets. Screen forms for updating are being developed; once they are complete the primary system will be modified so that it will back up data sets, only if the meta data are complete. The meta data system will change from permissive to restrictive: it will not only allow the meta data to be complete and accurate; it will require them.

The tight bond between the primary and the meta data systems is illustrated in the new way that the primary system is dependent upon the meta data system: the data base in the central directory must be available constantly so that the meta data system can update the meta data in the central directory. As the meta data and the data sets become more tightly connected their respective systems will also and there will be a single system that does two functions: to create, update and store data sets and to maintain accurate and complete meta data on them.

DIRECTORIES OF DATA SETS

Directories of data sets provide lists of spatially referenced data sets; the Report on Current Status and Trends in Federal Digital (2) provides a list of data sets maintained by departments and agencies of the Federal Government. At first glance, one would think that directories could be compiled faster and that they would be more accurate and complete if they could be compiled directly from meta data maintained by holding agencies. After all, the meta data seem to answer the questions that are required of directories:

- what data sets are there
- what do they contain
- how good are they

But even if holding agencies actively maintained meta data, the meta data would pose the following difficulties:

- the formats of the holding agencies would be different, they would have different data base designs, the commercial data bases would be different (INGRES, ORACLE, INFO etc.) and the meta data would contain different text files that are not a part of the data base
- the meta data would assume a knowledge of the operations of the holding agencies

Standard interchange formats such as SAIF, would allow meta

data to at least be expressed in a common format. The meta data of holding agencies could be assembled in one data base system: they could be compared on common fields if the holding agencies could provide them. The common fields used in Current Status (2) were dataset name, acronym, category, type and coverage (2).

The assembly of meta data could be made more understandible if each holding agency summarized their meta data and carefully documented the codes and terms used.

APPENDIX A

EXAMPLE OF META DATA TEXT FILE
(portions of text have been removed for brevity)

01 JOBID: PE017201
02 OWNER: PRINCE EDWARD ISLAND SOIL SURVEY UNIT
03 ACCESS POLICY CODE: A - UNLIMITED ACCESS
04 PROVINCE: PRINCE EDWARD ISLAND
05 PROJECT: PRINCE EDWARD ISLAND 1:10K
REPORT NUMBER: 2
REPORT NAME : SOIL SURVEY OF PRINCE EDWARD ISLAND
MAP TITLE : PEI 11L/5E
REPORT CONTRIBUTION :
06 MAP/REPORT PRINTED PUBLICATION DATE: 1988
07 AUTHORS AND CONTRIBUTORS:

NAME	AFFILIATION
MACDOUGALL, J.I.	L.R.R.C., DEPARTMENT OF AGRICULTURE
VEER, C.	L.R.R.C., DEPARTMENT OF AGRICULTURE
WILSON, F.	P.E.I. DEPARTMENT OF AGRICULTURE

08 CONTACT PERSON AT CLBRR-LRD, OTTAWA:
09 PHOTOGRAPHY SCALE: 1:12,000
10 SIL: 2 (PRINTED ON 1:10,000 SCALE ORTHO PHOTO MAP)
11 OBSERVATION STRATEGY AND SUPPORTING DATA FOR:
Intensity level requested was for a survey at 1:20,000 scale. This was the approximate level of input on the cleared land, but somewhat less detailed in areas more difficult to traverse and map. Access was by both walking fields and driving roads. Observation density was very variable and depended upon familiarity of the surveyor with the terrain and the difficulty of access (extreme wetness and very dense shrub vegetation), and the complexity of soil pattern/association. Inspection density: Well drained 1 per 4 ha (est.). The slope phase was mainly derived by means of measuring 2 M contour intervals. Field checking proved this method to be far superior over stereographic interpretation. Drainage interpretation is dependable between the well drained and imperfect/poorly drained soils. Much less dependable is the moderately well-drained phase (short duration spring wetness) because soil morphology often expreses this condition very weakly. Less dependable are poorly drained areas in respect to mode of deposition and texture (and associated predictability of hydraulic conductivity etc.). In many instances this would not affect capability for agriculture.
45 modal profiles published.

12 SYMBOL CONFIGURATION INCLUDING CONCEPT OF SOIL MAP UNIT:
DIAGRAM AND EXPLANATION [TEXT REMOVED]

13 ANALYTICAL METHODS LIST :
- pH was determined electrometrically on a soil-liquid slurry, using water and calcium chloride (0.01 M.CaCl2).

- Organic matter was determined by wet combustion, colorometric method (Sims, J.R. and Haley, V.A. 1971 (Soil Sci. 112, 137-141)). Carbon was determined by induction furnace for profiles Tignish, O'Leary, Duvar, Margate.
- extractable Ca, Mg, K by atomic absorption. Extractable phosphorus by medium strength Bray method, calcium and potassium by extraction with NH4Ac adjusted to pH7. C.E.C. (permanent charge) extraction with 2N. NaCl after equilibration of the soil with 0.01 M CaCl2. Methods used by L.R.R.C. Analytical Services Laboratory
[TEXT REMOVED]

14 ESTIMATE OF RELIABILITY: 80% or higher for well drained soils.

15 LIST OF ORIGINAL CATEGORIES AND CONVERSIONS (OPTIONAL):
Soils (52 series including land types) converted in SMUF.

16 OTHER PROVINCIAL INTERPRETATIONS:

17 OTHER PROVINCIAL COMMENTS:

18 PFI UPDATE LOG:

DATE	PERSON	TASK	COMMENTS
1991/09/24	CLA	9107-7	CNP

19 OTHER COORDINATE TEXT (Optional - only present if DATUM and PROJECTN in CP03 contain "TEXT*"):

APPENDIX B

META DATA FIXED LENGTH FILES

DESCRIPTIVE NAME : JOBID FILE

This file contains one record for every data set. It contains the items JOBID and MAPTITLE. The supervisor of the National Soil Data Base initiates work on a data set by creating a record in this file.

JOBID - (Job Identification Number) a 10 character unique designation which specifies a location on the earth and defines the area, scale and projection of the data. This represents the unit of storage in the NSDB and is equivalent to the manuscript soil map. The first two characters are alpha and represent the province or territory (SP is used to designate special projects). The six numeric characters designate the year the project started (5th and 6th numbers), the number of maps in the project (3rd and 4th numbers) and the order of project within the year (i.e. 01 as the first two numbers indicates the first project). The ninth and tenth characters are reserved for special classifications in the NSDB (e.g. the same map area in UTM and table coordinates)

MAPTITLE - map title abbreviated to 30 characters or less

DESCRIPTIVE NAME: ATTRIBUTE LINKAGE STATUS FILE

The ATTRIBUTE LINKAGE STATUS FILE has one record for every data set. It contains items that describe the linkage with the soil name and layer data base. It applies only to the detail soil data sets - records for other data sets have items with blank values. The ATTRIBUTE LINKAGE STATUS FILE is defined as a separate file because it is updated by the specially trained users who are the Data Coordinators.

DESCRIPTIVE NAME: NSDB JOBID STATUS FILE

The NSDB JOBID STATUS FILE has one record for every data set. It contains the following items:

. the approximate position of the data set in latitude and longtitude
. the displacement of features in the data set from corresponding features in the topographic base
. planimetric parameters such as datum and projection

It is defined as a separate file because it is updated by a separate group called the National Soil Data Base Group.

DESCRIPTIVE NAME: NSDB COVERAGE STATUS FILE

The NSDB COVERAGE STATUS FILE has one record for every theme. A theme is an ARC/Info coverage, a data set would usually have a soil, a hydro and a cultural coverage.
Each record contains the following items:

. the name of the coverage
. the agency that contributed the coverage
. the date that the coverage was digitised
. the dates on which it was edited

It is defined as a separate file because it has many records for each data set. It is updated by the National Soil Data Base Group.

DESCRIPTIVE NAME: ACTIVITY LOG

The ACTIVITY LOG has one record for every activity performed on the data set. An example of an activity would be a correction made to add a new polygon to a soil coverage.
Each record contains the following items:

. the date the activity was performed
. the person that performed it
. a description of the activity

It is defined as a separate file because it has many records for each data set. It is updated by the National Soil Data Base Group.

DESCRIPTIVE NAME: DATA TRANSFER FILE

The DATA TRANSFER FILE has one record for every time that the data set is sent from the Ottawa Office. Data sets are sent to the regional soil offices of Agriculture Canada and to other agencies. Each record contains the following items:

. the date the data set was sent
. the name of the agency
. the contact person in the agency
. the export format of the data set
  (DLG, ARC EXPORT, DXF)

It is defined as a separate file because it has many records for each data set. It is updated by the National Soil Data Base Group and the Data Coordinators.

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SYSTÈME D'INFORMATION GÉOGRAPHIQUE: UN OUTIL POUR L'ASSURANCE DE QUALITÉ DE DONNÉES TOPOGRAPHIQUES

(Séance d'affichage)

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Résumé

Le Secteur des levés, de la cartographie et de la télédétection (S.L.C.T.) d'Énergie, mines et ressources (Canada) doit, tel que décrit dans son mandat, amasser l'information topographique numérique et la rendre accessible pour des applications de système d'information géographique (SIG). Pour accomplir ce mandat, le S.L.C.T. travaille présentement à l'implantation de la Base nationale de données topographiques (B.N.D.T.). L'acquisition de cette information topographique est réalisée en utilisant les techniques de stéréonumérisation, de numérisation automatique par balayage de cartes existantes et de télédétection. Après cette acquisition, l'information doit faire l'objet d'un processus d'assurance de qualité afin de rétroagir au niveau des équipes d'acquisition.

L'objectif de cette présentation est de décrire un SIG en tant qu'outil d'assurance de qualité de données B.N.D.T. Pour ce faire, nous développerons les points suivants: les données B.N.D.T. et leur validation; le développement d'une procédure d'assurance de qualité; et le SIG, un outil d'assurance de qualité.

En conclusion, les études préliminaires et le processus d'acquisition d'un SIG nous permettent de croire maintenant que les SIG représentent de bons outils d'assurance de qualité de données topographiques numériques.

Abstract

The Surveys, Mapping and Remote Sensing Sector (SMRSS) of the Department of Energy, Mines and Resources (Canada) has, a part of its mandate, to gather digital topographic data and make it usable for Geographic Information System (GIS) applications. To accomplish this mandate, the SMRSS is presently working on the implementation of the National Topographic Data Base (NTDB). Part of this is the data collection to populate the NTDB by stereodigitizing, scanning existing maps and remote sensing technologies. After the collection process, data must be inspected to give feedback to production projects.

The goal of this presentation is to describe GIS as a tool for the NTDB data validation. To meet this, we will develop the following topics: NTDB data, and its quality control; steps to achieve data quality control; GIS, a tool for the data quality control.

In conclusion, preliminary studies and the procurement process of a GIS indicate that GIS is a good tool for NTDB data validation.

Introduction

Le Centre canadien de géomatique (C.C.G.) est une division du Secteur des levés, de la cartographie et la de télédétection d'Énergie, mines et ressources, Canada. Le Centre a pour mandat de fournir de l'information topographique numérique sur le territoire canadien, le produit résultant est un bien public[1]. Ainsi, des milliers de jeux de données seront produits et offerts au public. Une telle production doit être l'objet d'une étape de contrôle de la qualité des données produites avant de les commercialiser. C'est l'assurance de qualité.

Concrètement, l'assurance de qualité comprend des vérifications basées sur des normes précises afin d'obtenir une information pertinente quant à leur respect. L'utilisation ultérieure de cette information variera en fonction des buts visés par l'organisme y ayant accès. Cette information peut aussi bien être associée aux données pour en informer l'usager ou bien, fournir une liste de corrections que le producteur devra apporter. Notre priorité est de s'en servir afin de fournir aux responsables de processus de production, une information pertinente et précise leur permettant d'influer sur leurs processus afin d'améliorer la qualité des données en résultant. Il est reconnu comme étant plus rentable d'obtenir des données de haute qualité à l'acquisition que de se contenter de données nécessitant des traitements ultérieurs et de réaliser les dits traitements.

Les données à évaluer proviendront de la production interne, du Secteur, de fichiers stéréonumérisés ou provenant du balayage de cartes existantes au 1/50 000, de la structuration à l'interne et à l'externe de fichiers déjà existants aux 1/50 000 et 1/250 000 et, finalement, de fichiers 1/50 000 balayés à l'externe (dans le cadre de P.D.T.I.G. et autres productions). À l'externe plusieurs producteurs sont impliqués. La multitude d'intrants amène une disparité dans les méthodes de production, donc possiblement de la qualité des données.

Acquisition d'un système d'information géographique

La décision de choisir un système d'information géographique en tant que plate-forme de développement se base sur les capacités de traitement de ce type de logiciel mais aussi, le besoin pour le C.C.G. de développer une expertise dans ce domaine et d'étudier les possibilités et les restrictions d'utilisation de données B.N.D.T. dans un SIG.

Des spécifications d'acquisition furent écrites[2]. Les principaux critères qui y sont mentionnés sont relatifs à la flexibilité que devait offrir le système, à l'autonomie des stations de travail, au respect de la structure de données B.N.D.T. et de la qualité et quantité d'utilitaires et de logiciels offrant une plate-forme de développement la plus complète et conviviale possible. Tout critère inhérent à l'assurance de qualité de données ne put qu'être général, car au moment de l'acquisition, les spécifications précises permettant d'acquérir le SIG le plus apte à réaliser les manipulations de validation n'étaient pas entièrement définies. Trois postes autonomes de travail furent acquis en avril 1991.

Définition du système d'assurance de qualité

Des analyses et études, préliminaires au projet de développement, ont permis de définir les principaux paramètres définissant les grandes lignes de développement d'un système d'assurance de qualité de données topographiques numériques. Entre autres, identification des concepts qui feront l'objet d'une vérification, estimation du nombre de fichiers qui devront être l'objet d'une vérification lorsque le système sera pleinement en opération, for-

mation sur le nouvel équipement, estimation des possibilités de vérification du SIG, investigation de processus existants et analyse du modèle conceptuel de la B.N.D.T. pour l'implantation du modèle physique des données du SIG.

L'analyse du document des normes et spécifications de la B.N.D.T.[3] a permis de regrouper en 13 points majeurs l'ensemble des normes et spécifications décrites. Ces 13 points, nommés concepts B.N.D.T., devront théoriquement être l'objet des vérifications permettant l'assurance de qualité de données B.N.D.T. Ces points sont:

- définition du jeu de données (limites et étendue du jeu de données);
- exactitude du contenu (conformité avec la réalité topographique);
- intégrité de la codification (codes B.N.D.T. explicites: entité et attributs);
- dimensions minimales des éléments captés;
- altimétrie (équidistance et du non croisement des courbes de niveau, surface d'exclusion altimétrique, etc.);
- intégrité des données auxiliaires (du jeu de données et des entités);
- relation de connexion entre les entités;
- relation de partage entre les entités;
- segmentation des entités et de leur représentation géométrique;
- intégration des jeux de données (continuité spatiale des éléments de jeux de données adjacents);
- résolution des données;
- précision des données;
- respect du format d'échange «Canadian Council on Geomatics Interchange Format» (CCOGIF).

Avec 3 stations autonomes, nous disposons de beaucoup de temps CPU, qui géré adéquatement, constitue une capacité de production (traitements par lots) plus qu'intéressante. Le développement des outils doit s'axer sur l'utilisation de ce temps de traitement disponible, donc vers l'automatisation complète des processus. L'apport du cartographe devrait se limiter à gérer ces traitements automatisés, assurer la gestion des fichiers B.N.D.T. et réaliser quelques contrôles interactifs pour émettre un jugement ou s'assurer de la validité de la procédure.

De plus, malgré cette capacité de traitement, la quantité estimée de fichiers produits étant supérieure à la capacité de vérification, il n'est pas possible de réaliser la vérification de tous. Nous devrons intégrer une méthode d'échantillonnage au système afin que l'étape d'assurance de qualité ne constitue pas un point d'engorgement de la production de données B.N.D.T. Cette méthode est à définir.

Enfin, le système devra permettre de lire et d'écrire des données en format CCOGIF.

Donc, le système d'assurance de qualité, rendu opérationnel, comprendra une procédure opérationnelle gérant les processus automatisés pour la vérification des 13 concepts B.N.D.T. ainsi qu'une méthode scientifique d'échantillonnage. Il permettra la flexibilité nécessaire pour s'ajuster à tout intrant et à tout niveau de production. Le résultat de ce système devra permettre de fournir le «feedback» nécessaire pour que les producteurs améliorent leur processus de production et de contrôle de qualité interne.

La structure des données du système d'assurance de qualité

L'implantation du modèle physique de la base de données associée au SIG est réalisée en respectant, autant qu'il en est possible, le modèle conceptuel de la B.N.D.T. La structure des données du système d'assurance de qualité qui en résulte est brièvement présentée dans ce chapitre.

Trois objets composent cette structure, soit les entités, leurs représentations géométriques et les données auxiliaires. Les entités peuvent être représentées géométriquement de manière ponctuelle, linéaire ou surfacique. Pour certaines entités, plus d'une représentation géométrique peut leur être associée (ex: un barrage peut être représenté par un point, une ligne ou une surface). Une entité est dite simple si elle est géométriquement représentée d'une seule manière et complexe, si elle peut être géométriquement représentée de différentes manières. Des attributs sont associés à ces entités permettant de les spécifier. Par exemple, deux attributs sont attachés à l'entité «mine» permettant de décrire l'état et le type de mine.

Les représentations géométriques possibles sont le point, la ligne et la surface. Un attribut est également associé à la géométrie permettant de la qualifier. Par exemple, l'attribut d'une ligne permet de déterminer si la position planimétrique de la ligne est définie, indéfinie, approximative ou virtuelle.

Une entité surfacique peut être délimitée par plusieurs lignes tandis qu'une entité linéaire doit être associée à une seule ligne. Ces règles sont la base de la segmentation, c'est à dire que si la ligne est segmentée, l'entité linéaire associée est également segmentée. Les changements de valeurs d'attributs d'entité ou de ligne et les relations de connexion et de partage sont les seuls cas où la segmentation est permise. Ces relations de connexion et de partage sont exigées entre certaines entités. La connexion oblige que les entités impliquées partagent le même noeud au point d'intersection. La relation de partage exige que les entités linéaires et surfaciques impliquées partagent la même ligne lorsque la réalité topographique le dicte.

Les données auxiliaires, associées à la représentation géométrique, possèdent des attributs permettant d'associer aux données des informations relatives à l'acquisition, à la validation et à la description du jeu de données.

Les notions présentées dans les quelques lignes précédentes sont extraites du document «Base nationale de données topographiques: normes et spécifications»[4].

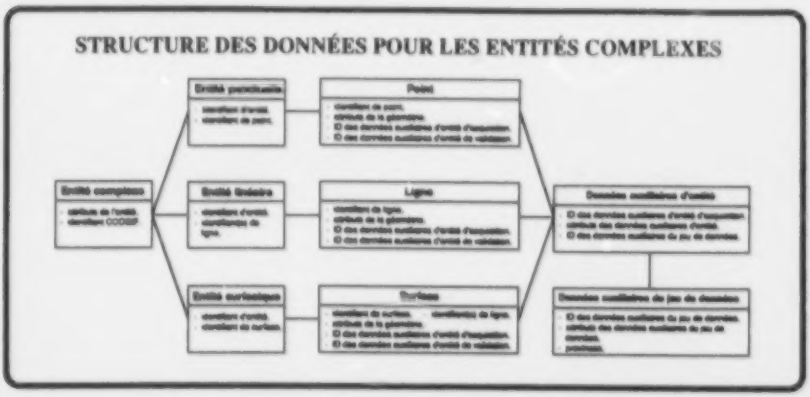

Figure 1: Structure des données pour les entités complexes.

La figure 1 représente la structure décrite, plus spécifiquement celle d'une entité complexe. Pour les entités simples, la structure est semblable, les attributs de l'entité et l'identifiant CCOGIF sont alors associés à l'entité simple (ponctuelle, linéaire ou surfacique). À cette structure B.N.D.T., le SIG génère des identifiants d'entités complexes, d'entités simples, de points, de lignes, de surfaces, de données auxiliaires d'entité, de données auxiliaires de jeu de données. Ces identifiants uniques sont les liens du modèle.

Le développement d'un système d'assurance de qualité

Dans une première phase, en considérant la faisabilité (physique et économique) ainsi que leur importance, la priorité de développement fut établie aux six concepts suivants, soit l'intégrité du format CCOGIF, l'intégrité de la codification, l'intégrité des données auxiliaires, le partage, la connexion et la segmentation.

Des sept concepts restant, un nouvel ordre de priorité sera réalisé. Il peut s'avérer possible que la vérification de certains de ces concepts s'avère non faisable. Dans ce sens, nous savons qu'il existe une méthode de vérifier l'intégrité de tous les concepts visés mais que pour certains, non seulement le nombre de méthodes s'avère limité, mais de plus, elles sont économiquement inadmissibles.

En respectant autant qu'il en était possible le modèle conceptuel de la B.N.D.T., le modèle physique de la base de données associée au SIG fut développé. L'interface de lecture du format CCOGIF au SIG fut également développé. Celle permettant l'écriture du SIG à CCOGIF est à réaliser.

La procédure opérationnelle du système est également à définir. Le temps de traitement d'un fichier (lecture, vérification automatisée et contrôle interactif) demeure un paramètre inconnu qui ne permet pas d'élaborer de scénarios précis. Une période expérimentale de mise en production du système d'assurance de qualité permettra de connaître les paramètres qui pourront permettre d'élaborer cette procédure opérationnelle et également, d'implanter une méthode scientifique d'échantillonnage.

Les outils

Ce qui distingue en partie un SIG d'un système cartographique est sa capacité de générer une information[8] à partir de traitement réalisé sur les données. C'est cette capacité que nous allons exploiter pour développer nos outils de validation. Par regroupement, comparaison, analyse spatiale ou autres manipulations de données, de nouvelles entités sont générées ou de nouveaux attributs ou de nouvelles valeurs d'attributs sont associés à des entités existantes afin de qualifier l'intégrité de chaque occurrence d'entités ou d'objets d'un fichier et cela, pour chacun des concepts choisis.

Peu d'applications standards sont disponibles pour la validation de données. Par contre, le SIG offre une véritable plate-forme de développement. Il permet, par sa vaste gamme d'utilitaires, de développer des applications conformes aux besoins spécifiques de l'usager. Ainsi, pour la validation de données, non seulement le développement des outils propres à la validation des concepts est techniquement réalisable, mais en plus, la flexibilité de définir les paramètres de sortie de ce traitement permet de retourner aux producteurs une information pertinente et adaptée aux objectifs du système d'assurance de qualité.

Le critère primordial pour le choix d'un outil de vérification est le degré d'automatisation qu'il permet. Pour nous, il se doit d'être maximal. Le type de traitement exigé ainsi que les dimensions de nos fichiers alourdissent énormément les temps de traitement interactif. Donc, tout traitement interactif est à éviter. Certains outils ne fonctionnent qu'interactivement, d'autres requièrent une intervention interactive à une étape du processus, et enfin, d'autres permettent une automatisation complète du processus.

Il est possible, avec les outils du SIG de détecter interactivement presque toutes carences d'intégrité aux 13 concepts identifiés. Une telle vérification, non automatisée, peut être laborieuse mais fort utile pour estimer la qualité des données en fonction des concepts ne faisant pas l'objet d'une vérification systématique ou simplement contrôler la validité des processus.

Les différents outils du SIG et du S.G.B.D. permettant le développement d'applications sont:

- utilitaires permettant l'écriture de requêtes;
- utilitaires permettant le développement d'applications spécifiques;
- éditeurs de commandes, de menus et de rapports;
- langage de programmation.

- Utilitaires permettant l'écriture de requêtes.

Le SIG et le S.G.B.D. associé possèdent de puissants systèmes de requêtes. Utilisant plusieurs opérateurs logiques, mathématiques, géométriques et de comparaison, ces systèmes permettent autant les requêtes interactives que les traitements par lots lancés d'un terminal alphanumérique. Les résultats de ces requêtes peuvent prendre la forme d'une série de tables, d'une sortie graphique ou d'une série de coordonnées ou d'identifiants d'objets, etc.

- Utilitaires permettant le développement d'applications spécifiques.

Autant le SIG que le S.G.B.D. offrent une plate-forme de développement pour des applications complexes. Ils offrent les outils permettant d'accéder à un type précis de données, de réaliser un traitement sur ces données et de générer une information de ces manipulations. De telles applications sont entièrement automatisées et peuvent être lancées d'un terminal alphanumérique.

Le SIG possède un ensemble de fonctions permettant de développer des applications spécifiques d'analyse de données en utilisant un langage de programmation tel que le langage C et une librairie de routines combinant des techniques d'analyse et les fonctions d'accès et de requête du système d'information géographique. Plus spécifiquement, le SIG offre des outils d'analyse spatiale ouvrant la porte à plusieurs applications de validation de la structure des données. Ces outils sont utilisables sur tout objet de la base de données, à savoir, les entités, leurs primitives (représentations géométriques) et les données auxiliaires. Entre autres, des opérateurs d'analyse spatiale permettent d'identifier les objets qui sont contigus, qui s'intersectent ou se qui superposent. De plus, toutes les possibilités de requête du SIG peuvent être intégrées à nos applications. Ce sont ces outils qui représentent la pierre angulaire sur laquelle nous développons les processus pour la validation de la segmentation et des relations de connexion et de partage[8]. Sommairement, les processus de vérification des deux concepts sont basés sur la comparaison entre deux sélections d'objets, soit les primitives partagées (résultat d'une requête) et les primitives superposées (résultat d'un opérateur de superposition).

Le S.G.B.D. offre les mêmes possibilités de requête. Les possibilités d'analyse spatiale sont cependant plus limitées. Il offre tout de même une bonne gamme d'opérateurs logiques, mathématiques, géométriques et de comparaison. Ses fonctions sont mieux adaptées au traitement de données alphanumériques (entités et attributs). Ainsi, en utilisant des opérateurs de comparaison, il est possible de valider une chaîne de caractères en comparant l'égalité avec une chaîne-témoin, de vérifier si telle valeur d'attribut est permise, etc. Ainsi, nous avons développé nos processus de vérification de l'intégrité de la codification et celle des données auxiliaires.

- Éditeurs de commandes, de menus et de rapports.

Autant le SIG que le S.G.B.D. donnent accès à des éditeurs de commandes, de menus et de rapports qui se greffent aux utilitaires de développement mentionnés auparavant. Ces utilitaires, qui adaptés à nos applications, permettent d'en faciliter l'utilisation, autant interactive que pour les traitements par lots.

- Langage de programmation.

La puissance d'un langage de programmation associé au SIG permet le développement d'applications complexes. Le système d'exploitation sur lequel repose le système supporte bien les applications constituant le système de validation. Les utilitaires permettant de gérer les traitements par lots permettent une flexibilité d'utilisation des applications développées et l'optimisation du temps CPU.

Conclusion

Les connaissances acquises des différentes analyses réalisées ainsi que l'expertise acquise suite au processus d'acquisition du SIG permettent de croire qu'un SIG constitue un outil flexible et efficace pour réaliser la validation de données topographiques numériques.

Le temps de développement nécessaire pour le système d'assurance de qualité est relativement court si on exclue la formation de base essentielle à l'utilisation de tout nouveau système. Le développement ayant débuté au mois de novembre, en parallèle avec certaines phases de formation, devrait se terminer au mois d'avril 1992.

En pleine période de production, nous estimons réaliser, avec trois stations, l'assurance de qualité des milliers de fichiers qui seront commercialisés par E.M.R. aux échelles 1/50 000 et 1/250 000 lors des prochaines années. La procédure d'assurance de qualité en développement offre la flexibilité nécessaire pour s'ajuster à un tel niveau de production.

Cette procédure d'assurance de qualité validera le contrôle de qualité des équipes de production. Par rétroaction, cette procédure fournira, aux responsables des processus de production, l'information nécessaire leur permettant d'améliorer leurs processus et ainsi produire des données de haute qualité. Ainsi, l'assurance de qualité permettra que les données commercialisées soient conformes aux spécifications et normes de la B.N.D.T., donc aux besoins des usagers.

Par la flexibilité de ses outils et la puissance des langages utilisés (4GL, langage C), le SIG offre une plate-forme ayant de hauts potentiels d'applications se prêtant bien à la validation de données. De plus, pour nous, l'utilisation d'un SIG s'avère un outil complémentaire aux

équipements du C.C.G. Entre autres, la validité du modèle conceptuel de données B.N.D.T. a pu être confirmée par l'implantation du modèle physique.

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PRODUITS INFORMATIQUES AU CENTRE CANADIEN DE GÉOMATIQUE

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Résumé

Au cours des dernières années, les nombreuses activités de recherche et développement menées au Centre canadien de géomatique du Secteur des levés, de la cartographie et de la télédétection ont conduit à l'élaboration de différents produits informatiques (logiciels, procédures, etc.) servant au traitement des données topographiques numériques. Cet article vise à présenter les principaux produits qui touchent des domaines aussi variés que la numérisation automatique par balayage, la stéréonumérisation, la télédétection, la normalisation des données, l'édition cartographique et la validation des données.

Abstract

During the last few years, the numerous research and development activities of the Canada Centre for Geomatics of the Surveys, Mapping and Remote Sensing Sector have lead to the development of a variety of computer products (software, procedures, etc.) used to process digital topographic data. This paper presents the most important products which are used in fields as diversified as scanning, stereodigitizing, remote sensing, data standardization, cartographic editing and data validation.

1. INTRODUCTION

Cet article a pour but de faire connaître les principaux produits informatiques du Centre canadien de géomatique (CCG) afin d'en faire bénéficier l'ensemble de la communauté géomatique.

Dans un premier temps, nous donnerons un aperçu des normes et spécifications produites au CCG, et dans un deuxième temps, nous présenterons les produits informatiques développés par les équipes des projet de balayage, stéréonumérisation, télédétection, normalisation des données, édition cartographique, validation des données et acquisition de données à forfait.

2. NORMES ET SPÉCIFICATIONS

L'établissement et la tenue à jour de la Base nationale de données topographiques (BNDT) est la première priorité du CCG. À cette fin, l'élaboration de normes assurant l'uniformité de la BNDT est essentiel. Le CCG et la Division de la cartographie topographique ont produit, en 1990, une première édition du document "Base nationale de données topographiques : normes et spécifications". Une deuxième édition a paru en avril 1991. Des spécifications complémentaires ont également été produites pour la numérisation automatique par balayage, la stéréonumérisation et la normalisation des données.

Le format retenu pour l'échange des données de la BNDT est celui du Conseil canadien de géomatique (CCOGIF). Une description complète de CCOGIF se retrouve dans le document "Format de fichier informatique pour l'échange de données topographiques numériques, version #1.2, janvier 1989" qui constitue la partie III du volume I de la "Norme nationale pour l'échange de données topographiques numériques".

3. LA NUMÉRISATION AUTOMATIQUE PAR BALAYAGE

En 1988, le CCG a reçu le mandat de faire l'acquisition d'un système permettant la numérisation automatique de cartes topographiques conventionnelles à l'échelle de 1/50 000. Le système répondant le mieux aux exigences s'est avéré être une

combinaison d'équipements et logiciels des compagnies Intergraph et Laser-Scan. Intergraph a été identifié pour le captage et l'édition de données matricielles et Laser-Scan a été retenu pour la vectorisation et l'édition de données vectorielles.

À l'aide de ce système, le CCG a produit 306 jeux de données de 1989 à 1991 selon les spécifications techniques "Numérisation du matériel reprographique à l'échelle de 1/50 000 et représentation des données" et, en 1991-92, 44 jeux de données selon les normes de la BNDT.

Le processus de production des données balayées se divise en cinq étapes, à savoir : la préparation des documents reprographiques et le balayage, la vectorisation et l'édition, l'intégration et la structuration, la vérification et l'inspection ainsi que la correction et l'archivage.

De nombreux outils informatiques ont été créés. Les principaux sont : la codification automatique des rives et des rivières, la vérification par fenêtre, la vérification de l'orientation des symboles, le traitement semi-automatique de la végétation à partir de la végétation et de l'hydrographie, le traitement semi-automatique de la végétation à partir des masques de clairières et de l'hydrographie, l'édition semi-automatique de l'hypsographie, la détection de l'absence ou de la présence de croisements à l'aide de tables de relations de connexion et de partage, l'application automatique de couleurs basée sur l'élévation des courbes de niveaux pour fins de contrôle de qualité, la structuration des éléments selon une table de priorités, la détection sélective des bouts libres en erreur, la transformation des éléments en NAD83, la duplication des lignes et la formation des surfaces, la vérification automatique de la structure du fichier ainsi que le traitement automatique des données en structure BNDT.

Les équipements utilisés par l'équipe de balayage sont des postes de travail Laser-Scan, munis d'outils informatiques développés au CCG et d'outils élaborés par Laser-Scan (LITES2, VTRAK), gérés par le système d'exploitation VMS.

4. LA STÉRÉONUMÉRISATION

L'équipe de stéréonumérisation a développé et implanté un système pour le captage de données topographiques à l'échelle de 1/50 000. En utilisant ce système, le CCG a produit 3 jeux de données en 1989-90 et 12 jeux de données en 1990-91 selon les normes de la BNDT.

Les équipements utilisés étaient des stéréorestituteurs numériques B8S munis d'un mécanisme de superposition. Ce mécanisme permet de diminuer considérablement les erreurs d'omission au captage et d'uniformiser le captage à l'intérieur d'un même modèle.

Le processus de production se divise en quatre étapes, à savoir : le captage, la validation, l'inspection et la structuration.

Le système de stéréonumérisation, qui consiste en un ensemble d'outils informatiques développés sur Intergraph, permet de connecter et de segmenter les données rigoureusement, en trois dimensions, pour répondre aux critères suivants : la fermeture mathématique, la segmentation telles que demandées par la BNDT, l'ajustement planimétrique entre les jeux de données qui sont sur le même système de référence et la construction des polygones en dupliquant les lignes et en leur assignant une directionnalité.

5. LA TÉLÉDÉTECTION

En septembre 1989, l'équipe responsable du projet SINAPS (Système INtégré d'Acquisition Par Satellite) a entrepris le développement d'un prototype d'acquisition de données topographiques à l'échelle de 1/50 000 utilisant la télédétection. Suite aux résultats obtenus, un projet de production a débuté. Ce projet permettra la révision de données topographiques numériques et sera fonctionnel durant l'année financière 1992-93.

Le projet peut être décrit sommairement par les étapes suivantes : l'acquisition des données, la correction géométrique, le pré-traitement, l'extraction manuelle et l'extraction automatique.

Des outils pour optimiser l'acquisition et l'utilisation des images, en tenant compte des caractéristiques spatiales et spectrales du capteur, ont été développés. Des cartes de nébulosité ont été produites et un logiciel pour prédire la visibilité d'un point donné, pour une période donnée, a été réalisé.

La correction géométrique des images est primordiale en cartographie topographique. Or, la correction polynomiale que l'on utilise habituellement ne donne pas la précision qu'exige une carte à l'échelle de 1/50 000. Un logiciel de correction géométrique, employant contrôle au sol et modèles numériques d'élévation, a été développé conjointement avec le Centre canadien de télédétection. Parallèlement à ces activités, de nombreux projets ont étudié la création de modèles numériques d'élévation.

Des logiciels de pré-traitement visant à effectuer des corrections radiométriques à l'aide d'un modèle atmosphérique élémentaire et d'échantillons au sol ont été mis au point.

Des procédures d'extraction manuelle ont été mis au point. Ainsi, des éléments des jeux de données ont été extraits et codifiés par interprétation visuelle.

L'approche numérique (classification) est généralement favorisée comme méthode d'extraction automatique de l'information. Les surfaces ont été extraites à l'aide d'algorithmes de classification par maximum de vraisemblance ou par parallélépipèdes. Un algorithme d'extraction des éléments linéaires (routes, rivières) a été développé. Celui-ci utilise les réponses spectrales des pixels voisins afin de déterminer si le pixel appartient à une ligne.

Les équipements utilisés pour la révision des données seront des postes de travail Intergraph et Laser-Scan gérés par les systèmes d'exploitation UNIX et VMS respectivement.

6. LA NORMALISATION DES DONNÉES

La normalisation des données consiste à rendre des données numériques et de différentes provenances conformes aux normes de la BNDT.

Une approche globale fut mise de l'avant afin de faciliter la conception d'un processus de normalisation des données. Ce processus est constitué de quatre phases principales, elles-mêmes subdivisées en plusieurs étapes.

La première phase du processus de normalisation contient l'ensemble des opérations de cueillette de l'information et de traitements préliminaires. Elle permet la qualification des données et l'aplanissement des divergences fondamentales. Les principales étapes de cette phase sont : le transfert des données en format de travail du CCG, la transformation des coordonnées selon la projection UTM, la transformation des coordonnées à NAD83 ainsi que le découpage et l'assemblage des feuillets selon le système national de référence cartographique. S'il s'agit de données stéréonumérisées, ces traitements sont effectués sur des équipements Intergraph alors que les données balayées sont traitées sur Laser-Scan.

La deuxième phase du processus de normalisation contient l'ensemble des opérations de corrélation des éléments topographiques avec les codes de travail développés au CCG. Les principales étapes de cette phase sont : la codification des éléments et la correction de la corrélation. Ces étapes peuvent s'effectuer sur Intergraph ou Laser-Scan et un logiciel pour passer d'un environnement à l'autre a été développé.

Les deux premières phases du processus de normalisation constituent l'uniformisation des données. Le CCG a développé un processus d'uniformisation des données balayées à 1/50 000.

La troisième phase du processus de normalisation contient l'ensemble des opérations de structuration des données en fonction du modèle de la BNDT. Les principales étapes de cette phase sont : l'élimination de la duplication et de la double numérisation, la fermeture mathématique, la segmentation, la construction et l'autonomie des surfaces, l'identification des surfaces (inclusion/exclusion), le chaînage des composantes

graphiques linéaires, l'ajustement planimétrique entre les jeux de données ainsi que l'identification des relations de partage. Ces différentes étapes sont regroupées dans un processus de structuration des données qui fonctionne sur des postes de travail Laser-Scan, à partir d'outils informatiques élaborés par le CCG, gérés par le système d'exploitation VMS.

La quatrième phase du processus de normalisation contient l'ensemble des opérations de préparation des données en vue de leur transfert vers la BNDT en format CCOGIF. Les principales étapes de cette phase sont : la création des méta-données et le transfert des données en format CCOGIF.

Des procédures ont été élaborés de façon à automatiser et à intégrer chacun des traitements effectués lors de la normalisation des données.

7. L'ÉDITION CARTOGRAPHIQUE

L'équipe d'édition cartographique a mis en place un système numérique d'édition cartographique et a procédé à l'édition de 3 fichiers de position pour la confection de cartes lors de l'année financière 1990-91.

Pour ce faire, l'équipe a établi un processus d'édition cartographique complètement informatisé et a développé les procédures qui s'y rattachent. Ce processus comporte les étapes suivantes : l'intégration des données, l'édition en lot, l'édition interactive, l'inspection de l'édition, le positionnement des écritures, l'inspection des écritures, le contrôle de qualité et le transfert des données à la Division des produits et services.

L'édition en lot traite l'information de façon systématique, sans que l'intervention humaine soit nécessaire. Les opérations qui y sont exécutées visent, entres autres, l'élimination des éléments n'atteignant pas les dimensions minimales et l'attribution à certains éléments de leur symbolisation finale (ponts, cours d'eau à deux rives, etc). Ces traitements produisent des fichiers statistiques sur les erreurs identifiées pendant le traitement et sur les éléments traités avec succès.

Des outils informatiques ont été développés pour l'édition interactive. Certains de ces outils visent l'exécution de tâches d'édition simples (déplacement d'un élément, rotation), alors que d'autres, plus complexes, permettent à l'opérateur d'interagir avec l'outil en modifiant certains paramètres selon le cas à traiter.

Le positionnement des écritures s'effectue en trois grandes étapes : la génération automatique du cadre et du quadrillage UTM, le positionnement des écritures sur la face de la carte ainsi que le positionnement de l'habillage. Tout le texte de la carte est d'abord intégré de façon automatique dans le fichier en position approximative. Le positionnement final de chaque toponyme se fait interactivement en utilisant une série d'outils informatiques qui permettent d'effectuer les manipulations nécessaires.

Les équipements utilisés pour l'édition cartographique sont des postes de travail Laser-Scan, munis de digimètre, gérés par le système d'exploitation VMS.

8. LA VALIDATION DES DONNÉES

L'équipe de validation des données met actuellement en place une série de processus de vérification automatique de la conformité des concepts de la BNDT en utilisant comme plate-forme de développement le système d'information géographique SYSTEM_9.

Dans une première phase, elle développe les processus nécessaires à la vérification automatique de cinq concepts, à savoir : l'intégrité de la codification, la connexion, le partage, la segmentation et l'intégrité des données auxiliaires. Ces processus seront fonctionnels au mois d'avril 1992. La lecture des données permettra de vérifier une partie de la conformité du format CCOGIF.

Dans une deuxième phase, elle définira l'ordre de priorité pour le développement des processus nécessaires à la vérification des autres concepts, à savoir : la définition des jeux de données, l'exactitude du contenu, les dimensions minimales, l'altimétrie, l'intégration des jeux de données, la résolution et la précision. Les développements seront réalisés selon l'ordre établi.

Dans sa version initiale, le système de validation proposé permet essentiellement la détection d'erreurs dont le concept est vérifié. Les erreurs seront rapportées aux équipes de production.

Les équipements utilisés pour la validation des données sont des postes de travail SUN gérés par le système d'exploitation UNIX.

9. L'ACQUISITION DE DONNÉES À FORFAIT

Le mandat de l'équipe d'acquisition de données à forfait est de développer un mécanisme d'acquisition de données à forfait qui rencontrent les normes de la BNDT et de procéder à l'émission de contrats pour l'obtention de jeux de données. Le processus d'acquisition doit supporter les activités du Programme de développement de la technologie de l'information géographique ainsi que du Programme national d'information topographique. Ces activités se scindent en trois groupes : la numérisation automatique par balayage, la structuration des données et la stéréonumérisation.

Une partie de la procédure d'inspection des données produites à forfait est automatisée. Des logiciels ont été développés et les composantes vérifiées par ceux-ci sont : la représentation géométrique, le qualificatif autorisé de représentation géométrique, la codification, la relation de connexion, la segmentation, la cardinalité, la validité des attributs variables, le système de coordonnées, la dimension du jeu de données, les unités, l'intégrité des courbes de niveaux et la fermeture mathématique des surfaces.

Des logiciels ont été développés afin de pouvoir superposer des jeux de données vectoriels sur les images matricielles résultant du balayage de la carte papier lors des travaux d'inspection à l'écran.

Les équipements utilisés pour l'inspection des données produites à forfait sont des postes de travail Laser-Scan gérés par le système d'exploitation VMS.

10. SOMMAIRE

La grande diversité des travaux du CCG a impliqué le développement d'une variété de produits informatiques. La majorité de ceux-ci sont disponibles maintenant. Ces produits sont fonctionnels dans des environnements de travail propres au CCG (Intergraph, Laser-Scan). Les gens intéressés à se porter acquéreurs doivent prévoir des ajustements aux produits initiaux. Pour obtenir plus d'information, veuillez écrire à l'adresse mentionnée précédemment. De plus, des fiches descriptives des principaux produits seront disponibles lors de la conférence SIG 92.

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BIOGRAPHIES

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A Canadian Standard for Interchange of Spatial Data
Let's play SAIF

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Abstract

On June 26, 1991 the Committee on Geomatics of the Canadian General Standards Board (CGSB-COG) has committed to the development of a Canadian Geomatics Interchange Standard (CGIS) to be based on the Spatial Archive and Interchange Format (SAIF pronounced SAFE). SAIF was originally developed in British Columbia. It is now a draft standard of the CGSB-COG.

The selection of SAIF as our draft Canadian standard took two years. The decision was based on both technical and non-technical merits.

What is SAIF? How is CGIS going to change the way we do geomatics in Canada? How will it benefit you?

The standardization process has given us a draft specification document but most of the work is yet to be done. How do we go from a paper document to a commonly used and appreciated standard? Its a long and difficult road to Standard Land. The CGSB-COG has developed a National Implementation and Transition Strategy. This paper will present the workplan and report on the ongoing activities.

Une norme Canadienne pour l'échange de données géomatique
Canada joue la carte SAIF

Résumé

Le 26 juin 1991, le comité sur la géomatique de l'Office des normes générales du Canada (ONGC-CSG) a pris la décision de développer une norme canadienne pour l'échange de données géomatiques (CGIS). La nouvelle norme sera basée sur le format pour l'archivage et l'échange de données à référence spatiale (SAIF prononcer séfe). SAIF a été développée en Colombie-Britanique. La norme SAIF est maintenant une ébauche du ONGC-CSG.

La sélection dc 3AIF pris deux ans. La décision fut prise en fonction de ses mérites techniques et non-techniques.

Qu'est ce que SAIF? De quelle façon CGIS va t'elle changer la géomatique au Canada? Quel seront les bénéfices pour vous?

Le processus de normalisation nous a donné une ébauche de norme, il reste cependant la plus grande partie du travail a faire. Comment passer d'une norme papier à une norme couramment utilisée et appréciée par la communauté géomatique. Le ONGC-CSG a développé une stratégie nationale d'implantation et de transition. Cette communication présente le plan de travail et donne un compte rendu des activités en cours.

Multiple Criteria Decision Analysis as a Method for Quality Assurance in GIS.

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Abstract

Quality assurance is an area of applied GIS which is growing in importance. At present much of the current research involves the use of complex statistical techniques which require large amounts of processing power and are difficult to comprehend by potential users.

This paper will outline research underway at the University of Salford towards developing a hierarchical structure for assigning significance and weights to error sources in spatial information (see also Coward and Heywood, 1991). This approach forms the basic building blocks for a user centred approach to quality assurance. The techniques employed draw upon Multiple Criteria Decision Analysis (MCDA) as a working methodology. The model described here is implemented using proceedures which already exist in the SPANS GIS.

The generic nature of the MCD approach would, however, allow its use acress a wide range of application environments. To illustrate the concepts and methods which underpin the MCDA approach, a model focussing on spatial decision making in environmental planning will be discussed. The database used to test the model was generated as part of a joint UK/Czechoslovakian venture.

What many users require is a quick data appraisal which will act as a preliminary guide to the quality of the information produced by their geo-processing activities. This paper argues that many of the proprietry GIS systems in the market place already contain the necessary functionality to implement quality assessment proceedures without deleloping "bolt on" modules.

ANALYSE DE DÉCISION REPOSANT SUR DES CRITÈRES MULTIPLES, MÉTHODE DE CONTRÔLE DE LA QUALITÉ DES SIG.

RÉSUMÉ

Dans les diverses applications des SIG, le contrôle de la qualité revêt de plus en plus d'importance. À l'heure actuelle, les chercheurs se servent de techniques statistiques complexes, nécessitant une grande puissance de traitement, que les utilisateurs potentiels auront de la difficulté à comprendre.

Ce document porte sur les recherches effectuées à l'Université de Salford en vue de l'établissement d'une structure hiérarchique pour l'attribution de codes d'importance et de pondération aux sources d'erreurs dans les informations à référence spatiale. C'est à l'aide de cette structure qu'on compte mettre au point une méthode de contrôle de la qualité facile à utiliser. Les techniques employées s'inspirent de la Mutliple Criteria Decision Analysis (MCDA) (analyse de décision reposant sur des critères multiples) comme méthodologie de travail.

Cette approche générale peut être employée pour toute une gamme de milieux d'application. Afin d'illustrer les concepts et les méthodes sur lesquels repose l'approche, on examinera une étude de cas portant sur les prises de décision à référence spatiale dans le domaine de la planification environnementale.

1. INTRODUCTION

There is an old adage, "Don't believe everything you see". This is taken to heart by most people in many situtions. One, for example, is inclined not to believe some of the incredible stories portrayed in national daily tabloid papers. This sceptical approach is, it appears, not one which is carried through our approach to cartographic data sources.

A questionnaire was recently circulated to users of SPANS GIS and yielded some surprising, or perhaps not so surprising results. Twenty nine responses were received from a mailshot of sixty eight and while the authors don't consider the results to an entirely true reflection of the global user community can be seen as a useful insight. Interesting responses were as follows;

Q. Do you encounter any data quality problems on your systems?

Yes	19
No	0
Sometimes	10

Q. Do you think these are due to:

Source Data Inaccuracies	17
Data Capture Inaccuracies	8
System Processing	4

Q. Do you Believe it is possible to assess data quality?

Yes	19
No	0
Sometimes	10

Q. In assessing results derived from spatial data do you allow for inaccuracies in potional accuracy?

Yes	11
No	7
Sometimes	11

Q. In assessing results derived from spatial data do you allow for inaccuracies in areal/attribute accuracy?

Yes	5
No	7
Sometimes	17

Q. What percentage of your data are accompanied by statements regarding data quality and/or appropriate uses for the data?

Less than 20%	22
21 to 40%	5
41 to 60%	1
61 to 80%	0
above 81%	1

What then, can be inferred from these results? Seventy six percent of respondents indicated that less than 20% of their data were accompanied by statements of accuacy or advice as to usage of the data. Only one respondent knew of the integrity of his data. Problems of data quality were regularly encountered by 66% of respondents while the other 34% stated that they sometimes encountered problems, no one said they have no data quality problems. Problems were considered to be heavily skewed towards source data inaccuracies and it is management of this problem that will be addressed in this paper.

What can be seen as an alarming statistic is that only 38% of users consider the positional accuracy of their source data when analysing the results of their spatial analysis, although all respondents believed that it was possible to assess the quality of their data. This figure is even lower at 17% for areal/attribute accuracy. This will, without doubt, lead to a long term reduction in the credibility if GIS solely because of the source data. This is a case of the tools, not the craftsman, who is at fault. This paper will endeavour to promote a way in which the user can evaluate his data and, therefore, his database through the use of GIS tools already at his/her disposal.

2. PROBLEMS OF UNCERTAINTY IN CARTOGRAPHIC DATA

Problems of uncertainty in cartographic data are now widely recognised and documented (Miller et al., 1989; Goodchild and Gopal, 1989; and Openshaw, 1990). To the detriment of an emerging discipline, the current favourite way to deal with error and uncertainty in GIS is to ignore it.

Four sorts of GIS error have been classified by Bedard (1987);

1) Conceptual uncertainty,
2) Spatial uncertainty,
3) Attibute uncertainty and
4) Meta uncertainty.

The first of these deal with the problems of translating the entities, states and problems which exist in the real world to the physical and cognitive models which for the basis of a GIS project. The second and third deal with the error

associated with the location and accuracy of feature attributes. The fourth, meta uncertainty refers to the certainty to which other types of uncertainty such are known. It is the view of the authors that some approaches currently suggested to deal with uncertainty are, while being totally valid within a small application area, are too complex and often beyond the comprehension of the average user who cannot afford to spend the time carrying out complex mathematical and statistical calculations. It is our belief that the individual user requires an 'holistic' approach to uncertainty. What he really wants to know is "how good is my data and how much can I rely upon the results of my spatial analysis?".

3. MULTIPLE CRITERIA DECISION ANALYSIS AS A TOOL FOR UNCERTAINTY EVALUATION

At the centre of Multiple Criteria Decision Analysis (MCDA) is the concept of making a decision (for example a best site) through the use of several decisions and considerations of several criteria rather than one "value judgement". Some decisions, such as dodging a flying missile, are instataneous while others, such as buying a new house, require a great deal of thought and deliberation. Decisions which are arrived at through deliberation are often "best fit" decision. This could be applied to the analogy of house buying. On one hand you need a bigger house for your family but on the other hand the loan repayments will be higher. In this situation some sort of judgement is required depending upon the criteria under consideration. Do you stay in the house you currently occupy and be kept awake all night by the kids or do you buy the new house and take on a second job to repay the loan? It is only through the evaluation of multiple criteria, often in a subconscious manner, that a decision can be reached.

The major advantage of a multi-criteria approach is the ability to take account of a whole "gamut" of differing, but relevant, criteria (Nijkamp and Van Delft, 1977).

4. A case study: ZDARSKE VRCHY (Czechoslovakia)

This case study was carried out using the Index overlay and Matrix overlay modules of SPANS GIS. These modules are Multiple Criteria Decision Analysis tools. The data for the case study was derived from Czechoslovakian tourist maps. These maps are notoriously uncertain in some areas as they were deliberately distorted by the Czech military so that they could not be used in any attack against the country. This distortion took the form of slicing out slivers, removing features and then reproducing the map.

The problem to be completed in the case study was to use MCDA to find the best, and most certain, area to site a hypothetical ski resort in the Zdarske Vrchy region of Czechoslovakia. Using the MCDA tool inherent within

SPANS it is easy to find the most effective site for the resort. These arithmetic overlay proceedures are a method of creating a new map layer by performing arithmetic operations on the features in each layer. In the index overlay method, entities are weighted according to their importance or worth and , the attribute values are scored according to their ability to reflect certain conditions imposed by the criteria of your application. Matrix overlay is a method of creating a new map layer by classifying the intersection of two layers. The SPANS index overlay model allows map arithmetic to be carried out on many data layers to find areas meeting requirements in all layers. This is done through the use of a formula;

$$\frac{(W1 \times S1) + (W1 \times S1) + (W1 \times S1)}{\Sigma W}$$

This formula is only one of several decision making algorithms which could have been used. Others are being considered as a part of ongoing research.

The data layers used were;

Relief
Roads (main)
Roads (minor)
Roads (forest tracks)
Slope
Settlement
Snow cover
Forest cover.

Each of these were assigned Weighting (W) values, these take the form of percentages relating to the importance of the one layer to the overall model. These data layers each have several divisions, or classifications. These were scored (S) on a scale of 10 - very important to -1 prohibitive, dependant upon how important the class within the data layer was to the final model. This relationship is shown in figure.1. The raster system then carried out a calculation using the above formula for each pixel and output the results. This method produced a raster map showing the distribution of areas of best fit, worst fit and intermediate solutions to the problem of best location (figure 2.).

At this point the majority of users will stop and present their results. These will be taken on board by the planners and a major blunder may have been propagated.

To overcome, or at least quantify, the uncertainty in the data or the solutions derived from the data the authors believe that a further step must be undertaken to generate an uncertainty surface. This can be done using the

method of Index Overlay which is already available within SPANS (Figure 3).

To this end a worker from the area of Zdarske Vrchy, Mr Pavel Brokes, was employed as an expert to quantify the accuracy of individual features within the map layers that would be used in the spatial analysis. He was able to give each feature within each map layer a level of certainty. This level is based upon his perception of uncertainty based upon;

a) Knowledge of data source accuracy
b) Knowledge about the purpose of the use of data.

These could then be substituted into the Index Overlay in the place of the score values, leaving the weightings unchanged from the best fit location model. This will then produce an uncertainty surface.

This is a useful tool in itself but not a final solution to the problem. The final solution can be attained by comparing the best fit and uncertainty surfaces to finad the best fit/most certain area. This is done using the SPANS Matrix overlay technique. Here one constructs a matrix of one map against the other, in this case best fit and certainty (figure 4).

5. CONCLUSIONS

Results can be, and have been attained by using the above methods to qualify ones results. A problem at the moment is, however, the need for communication with experts about the data to allow the modelling of the certainty surface. As demands from the user community for better communciation concerning the accuracy and shortfall of data becomes heard then the incorporation of such techniques will become easier and more widespread.

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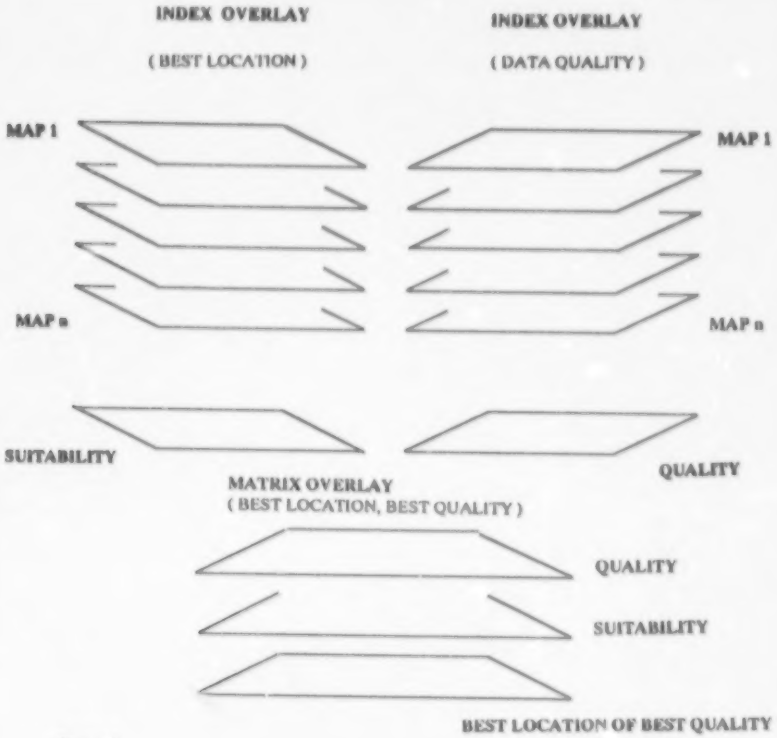
INDEX OVERLAY
(BEST LOCATION)
INDEX OVERLAY
(DATA QUALITY)
MAP 1
MAP n
MAP 1
MAP n
SUITABILITY
QUALITY
MATRIX OVERLAY
(BEST LOCATION, BEST QUALITY)
QUALITY
SUITABILITY
BEST LOCATION OF BEST QUALITY

Figure 1

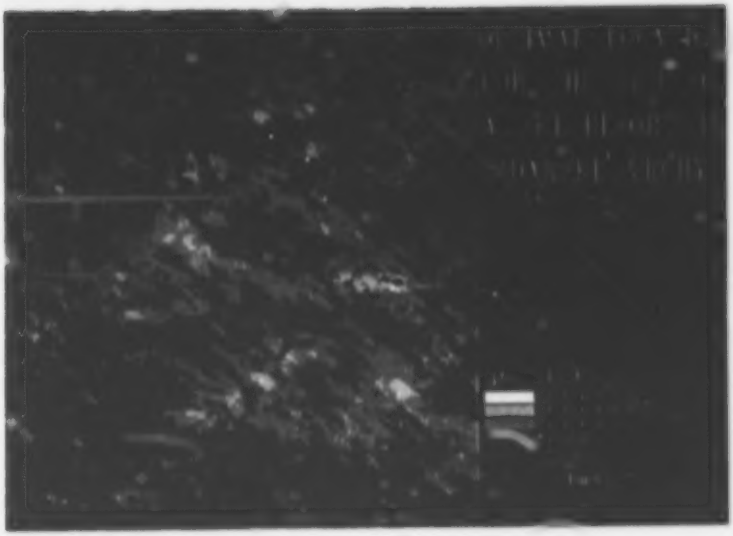

Figure 2.

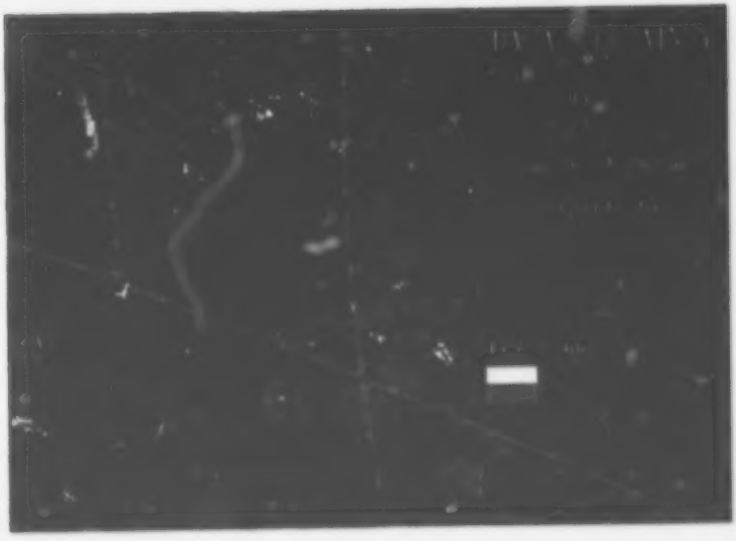

Figure 3.

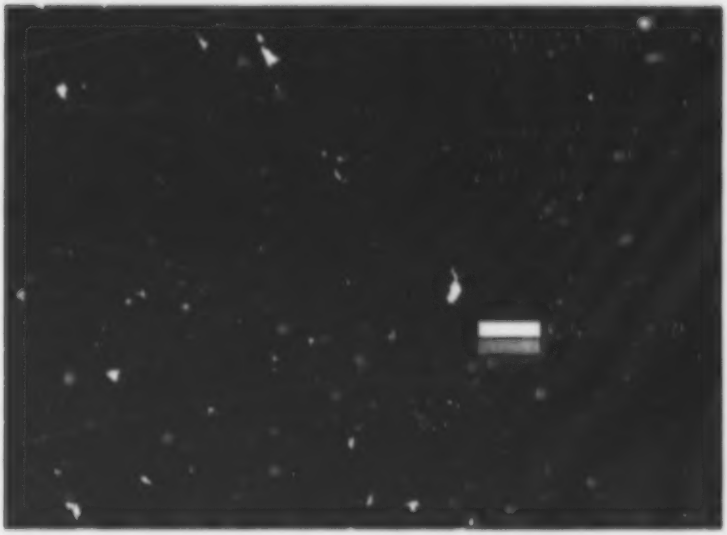

Figure 4.

INSTITUTIONAL CHANGE AND TECHNOLOGY: A FRAMEWORK FOR GIS TRAINING AND EDUCATION AT MNR.

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Abstract

The Ontario Ministry of Natural Resources (MNR) has undergone major institutional restructuring. At the same time, it has moved forward on its GIS implementation plan. The combination of a new vision, and the need for the application of GIS in Integrated Resource Management, necessitates a framework for GIS Training and Education.
The plan is based upon the following premises:

(1) a holistic, systemic view of Training and Education;
(2) an analysis of the demand for GIS skills;
(3) the supply of these skills through partnerships with both the private sector and the colleges and universities.

The approach is illustrated with specific strategies for all levels of the ministry.

CHANGEMENTS INSTITUTIONNELS ET TECHNOLOGIE
LE PLAN DU MRN DE FORMATION ET D'ÉDUCATION EN MATIÈRE DE SIG

RÉSUMÉ

Le ministère des Richesses naturelles a subi une profonde restructuration institutionnelle. En même temps, il a avancé dans sa stratégie de mise en place des SIG. La combinaison d'une optique, de buts et d'objectifs nouveaux, ainsi que la mise en place d'outils SIG dans la gestion intégrée des ressources, exigent une approche novatrice face à la formation et à l'éducation.

Le plan de formation et d'éducation en matière de SIG repose sur les concepts suivants :

1) une vision holistique et systémique de la formation et de l'éducation;
2) le besoin de cheminements d'apprentissage en SIG pour toutes les catégories de personnel du MRN;
3) des partenariats avec les organismes d'enseignements et le secteur privé.

Des initiatives précises incluent le perfectionnement du personnel du MRN au collège Sir Sanford Fleming. On a élaboré des projets de coopération pour ces étudiants et d'autres des universités de l'Ontario, dans le cadre de la mise en oeuvre des SIG.

En plus de cette approche ascendante au changement institutionnel, le département de la formation et de l'éducation en ressources informatiques a mis au point des occasions d'apprentissage pour les cadres supérieurs et les scientifiques de tout le Ministère.

1.INTRODUCTION

The Ontario Ministry of Natural Resources has been implementing Geographic Information System technology for almost a decade. Recent papers by staff describe the progress (Rollock 1990, Houweling 1991). Contemporarily, society, government and industry have evolved new views on the management of natural resources. Current thinking at MNR can be found in Direction '90s (MNR 1991a) and the ITSP Summary (MNR 1991b). Direction 90's emphasises three strategies: partnerships in resource management, valuing resources, improving the knowledge base, while the Information Technology Strategic Plan (ITSP) provides a management framework for the use of IT in support of these strategies. As part of the reorganization to meet these goals, the ministry has recognized the need to develop a framework for GIS training and education. This paper describes the framework to develop the expertise necessary for effective use of GIS.

2.THE GEOGRAPHIC INFRASTRUCTURE

The ministry has redefined its administrative units (Figure 1). There are four levels in the geographic hierarchy: area, district, region and main office. Each higher level contains a number of the lower units. The total number of each unit is listed in Table 1.

Area: the smallest geographic management unit. Each area inventory is maintained in a separate database. The province of Ontario can be space-exhaustively divided into the 113 areas.

District: an aggregation of a few areas (usually three or four). Smallest unit from an organizational perspective (i.e. equipment and specialist staff).

Region: an aggregation of districts. Each region has a Regional Information Resource Manager reporting directly to Main Office (IRD).

Main Office: the headquarters of the organization with a province-wide perspective. Main office may occupy several distinct geographic locations (i.e. Toronto, Haileybury, Peterborough).

3.THE STAFFING INFRASTRUCTURE

With this geography in mind, it is possible to develop a technical staffing model in support of GIS across the province (Figure 2). Four sets of GIS duties have been identified as part of the operational requirement: Data Technician, Geographic Information Systems Officer, GIS Applications Specialist, Project Manager (with GIS expertise).

Data Technician

For each Area, there have to be staff with the responsibility for the collection and loading of data into the GIS database. These staff should be knowledgeable in: field techniques, database loading, issues of data quality, access and analysis, general concepts of GIS.

Geographic Information Systems Officer (GISO)

For each GIS installation, the GISO needs to be familiar with all elements of GIS hardware and software: digitizing tables, plotters, graphic terminals, system interfaces, GIS, DBMS,

user interface.

GIS Applications Specialist

At each installation, the Application Specialist has to be familiar with the corporate GIS applications, user requirements, GIS functionality, problem-solving with GIS, application programming, customization of GIS for end-users, training/education of end users.

Project Manager

For each operational unit, the Project Manager should be familiar with GIS technology, its role within INRIS, and the ITSP. The manager needs an appreciation of staffing and training issues, data loading and standards, application development - corporate and local, plus database management.

There is a parallel need for specialist staff at the Main Office and Regional level. The duties can be divided into four categories:

a)Data Generation: Provincial Mapping Office (OBM) Toronto, Forest Resource Group (FRI) Sault Ste Marie and others.
These units require GIS Application Programmers, Database Programmers and Analysts.
b)Applications Development (Toronto): INRIS, ALPS and other corporate systems
ITPD has a need for both GIS Application Programmers and Analysts.
c)Training and Education (Toronto)
This unit within IMS requires GIS Education Specialists to develop curriculum and educational products in support of the GIS implementation plan.
d)Research
Within MNR there is a role for Research Scientists knowledgeable in GIS technology. They have to address: methodology concerns, data issues and technological advances.

4.CURRENT GIS TRAINING

GIS staff in the Ministry receive their training either prior to joining MNR, or they are given on-the-job training opportunities. The ministry can improve its human resource by continuing to hire graduates with previous GIS experience and also to enhance this knowledge once employed.

a) GIS Training prior to joining MNR.

An estimate of the formal GIS training options can be achieved by an analysis of current staff backgrounds. A significant percentage of the GIS technical professionals in MNR obtained their GIS skills at the College of Geographic Sciences in Nova Scotia through one of the twelve month post-graduate diploma program. The eight month program at Sir Sanford Fleming College in Lindsay, Ontario follows a similar format but with less emphasis on programming. MNR in September 1991 sent ten of its employees to the GIS Applications Specialist program, and it is currently working with the College to develop appropriate GIS co-operative projects for these students. At this time, there are not any specialized GIS programs offered at Canadian universities. The education initiatives of the National Science Foundation (NSF) funding the National Center for Geographic Analysis and Information (NCGIA) at UC Santa Barbara, SUNY Buffalo and University of Maine at Orono, in the United States or the Regional Research Laboratories (RRL) in the Great Britain have not

been replicated in Canada. Most Canadian universities have preferred to introduce the technology into existing disciplines e.g. Geography, Forestry or Survey Engineering.

b) On-the-job GIS training

Two methods for in-house training have been explored to date:

i) design and delivery of GIS courses by MNR staff;

ii) design and delivery of GIS courses by the private sector.

i) MNR courses

The former GATT group (GIS Applications and Technology Transfer), at MNR developed a one week 'Introduction to GIS ' course. Its purpose was to introduce basic concepts, reinforcing them with hands-on sessions with ARC/INFO, the prevalent system in the Ministry. This course has been offered 24 times and has been attended by 147 staff. In addition, the GATT group has also offered a few three day AML courses, usually as part of the Model District project.

ii) Non-MNR courses

With any major software system, there are normally system-specific courses for the users. Over the years, a number of MNR staff have been sent on courses held by ESRI Canada on the components of ARC/INFO and by TYDAC Technologies on SPANS. One of the problems with the output from these courses is that MNR has not maintained any inventory of the course attendees. With the move towards corporate standards for both GIS and DBMS, it becomes critical that MNR appreciate the nature and content of these specialist courses and maintain a record of staff who receive this particular knowledge. Recently, software development companies have started to offer training courses on the Application of GIS. These differ from vendor courses in that they are problem-oriented. The best example is the education program developed by Geomatics Int. for the Conservation Authorities, coordinated by Land and Water Policy Branch. Given a specific program, with a well-defined set of GIS educational needs, the courses are geared to the problem-solving tasks of the users. This type of focus is rarely available from the software vendors.

5.DEMAND ANALYSIS

Marble (1991), in his GIS training workshop for local and regional planners developed the concept of a triangle of users. He identified four levels of technical GIS user. The number in each group corresponds to the proportional area of the triangle. Figure 3 shows the four levels of user. The duties of each level are defined below.

1) GIS Technical Development: to develop new improved GIS software.

2) GIS System and GIS Application Designer: to work with generic problems of GIS design - develop user requirements, design spatial databases, implementation planning, design specialized GIS applications.

3) General GIS End User: work with the system at the command level but whose primary concern is still the results from the GIS.

4) GIS Application End User: work at routine spatial analysis tasks and who are isolated from the body of the GIS by 'application' programs written in 4GL.

Marble recognized the need for different education and training for each of these four levels. The two types of End User will be found within MNR. The GIS Application User may correspond to either Professional or Clerical staff. The General GIS User would be equivalent to the GIS Application Specialist from the program at Sir Sanford Fleming College. Within the ITPD Branch, there will be a number of GIS System and Application Designers. The top category of GIS Technical Development will be likely found either in university research or a software vendor environment.

The staff hierarchy can be mapped into a similar triangle, based upon Management skills (Figure 3). Each of the four levels has slightly different terminology at the Main Office, Region, District geographic unit (Table 2). Table 3 shows the equivalent technical skills at each geographic level.

For each of the four levels, it is possible to identify the demand for GIS training and education.

Level 1: Senior Management
The decision makers must understand the fundamental concepts of GIS, appreciate the status of the technology within the ministry, know the steps in GIS Planning and be familiar with the management issues. This can be accomplished by a two day GIS Management seminar. In this circumstance, the objective is education and not training.

Level 2: Middle Management
This level has been divided into two categories. Level 2a has similar requirements as Level 1, whereas Level 2b needs some formal training in GIS. This training should be, at minimum, a one week hands-on course devoted to current GIS applications in MNR, plus the future potential.

Level 3: Professional and Technical Staff
These staff will require the education and training specified for Level 2b, and additional technical courses, based upon the various GIS subsystems or complementary technologies.

Level 4: Clerical Staff
Clerical staff must become familiar with data collection, preparation and database loading procedures. These technical courses will be supplemented by conceptual courses for broad understanding.

6. SUPPLY ANALYSIS

Given this range of demands for Education and Training, there are two main categories of supply: the private sector and the academic institutions. Each of these categories can, in turn,

be subdivided;

Private Sector:	Consultant Application Developer Vendor
Academic:	College University

The leading edge of GIS implementation lies in the private sector. While these companies do not have to adopt the long-term commitment of government, they do have to use the best available tools to stay competitive. In general, the academic institutions do not have the technological resources or inter-disciplinary environment to make a significant contribution on the larger implementation issues. Their realm tends to be methodological, conceptual and usually discipline-specific.

Private Sector

The three subcategories represent a continuum. There are very few GIS consultants. These companies tend to focus on the feasibility studies, system design and analysis. The application developer will have the skills to take a functional requirement study and to develop a customized application. The vendor will market the software, supporting clients through maintenance contracts and training courses. All of these companies can provide education and training. The consultants may concentrate on the concepts and methods. The application developers can offer specialized courses on problem solving, using particular programming tools. The vendor will normally offer generic courses, reflecting the components of their software product.

Academic Sector

There has been some debate in academic circles about the distinction between education and training. Universities tend to see themselves in the education market, whereas technical colleges are not uncomfortable with the training mandate. In practise, the two realms overlap, and society needs both sets of abilities: conceptual understanding and technical know-how.

Technical colleges, through their diploma programs, can produce technicians or technologists with particular practical knowledge relevant to jobs in the marketplace.
The universities have a mandate for teaching and research. In the field of GIS, they can contribute to the development of new methods of analysis, new algorithms and conceptual models. Given the complexities of current GIS, this type of work is most likely to occur at the graduate level.

Partnerships

In the current economic climate, there will be a demand for creative partnerships. The universities and colleges can offer education and training; the private sector can provide technical knowledge and access to the technology. For the ministry, there is the opportunity for collaboration over complex learning issues, based upon the resource management problems, applied research and the development of the human resources for successful implementation.

7. STRATEGIES

The overall strategy has been to develop a systemic view of the training and education problem: identifying the levels of demand, the types of courses and the potential suppliers. One general strategy is to approach the problem from both ends: top-down and bottom-up. The top-down method begins with an education program for all management, affected by the new technology. This awareness development must precede all other actions. The bottom-up method has begun with the support of ten MNR employees in the GIS Application Specialist at Sir Sanford Fleming College. In this case, individuals at the Technical Staff level will be given new practical skills to complement their existing knowledge of the ministry business.

Level 1: Senior Management
In the new fiscal year 1992-93 all senior and middle managers will be provided with a two day GIS Management course. The course should be offered at four locations across the province, preferably in association with a university or college. The course should be scheduled within a three month period. This course would be followed by an intensive hands-on one week course for all managers with direct responsibility for GIS implementation. The course will not be 'once-off' but will be followed by updating seminars on a regular basis.

Level 2: Middle Management
There will be a cadre of technical managers who will need direct hands-on experience with the corporate GIS. These managers can expect to be involved with daily technical decisions on issues presented by professional, technical and clerical staff.
The one week course will give the opportunity to use, understand and modify the applications developed in the Model District project, the Plonski project and the Shoreline Management program.

Level 3: Professional and Technical Staff
Professional and technical staff with GIS knowledge will be needed on the Area teams, in the District and Regional offices and in support at Main Office. These staff will need retraining, in the sense of the GIS Application Specialist diploma program and specialist courses from the vendor environment.

Level 4: Clerical Staff
There is an opportunity to redeploy clerical staff within a GIS environment. Particular tasks could include data preparation, data loading, verification and routine analysis. The size of this task depends on the desire for decentralisation and standardisation of data capture.

Other Strategies (Non-level specific)

1) Research
While the ministry will continue to develop partnerships with the academic community for research purposes, it is important that within the ministry there is the capacity to undertake applied research in the use of GIS.

2) Learning Resource Centre
The Main Office should act as a learning resource centre on GIS publications, educational and training resources, including videos, software, workbooks etc.

3) Correapondence Course
The time is coming when staff will want to learn about GIS technology in their own time, on their own or office micro-computer. Correspondence courses, following the Open University concept, could be used to upgrade any interested ministry staff. The course would include a number of practical exercises and two or three weekend tutorial retreats per year.

4) High School Course
In the future, the ministry should expect better technical skills from high school graduates. It can make a contribution by working with high school teachers to provide materials for class room learning, based on MNR data sources and problems applying GIS tools.

5) Inter-ministry Cooperation
The application of GIS technology is not limited to MNR. GIS staff development could benefit from a sharing of ideas, teaching and equipment resources. In the future, we can anticipate the sharing of ideas between a number of ministries, for example, Environment, Health and Transportation.

8. SUMMARY

The Ministry of Natural Resources has undergone a major restructuring this fiscal year (1991-2). At the same time, it has moved forward rapidly on its GIS implementation strategy. The combination presents an opportunity for strategic GIS Training and Education planning.

The author has described the new organization, both structurally and geographically. This is followed by a demand/supply analysis of GIS training needs for each of the technical and managerial levels. From this analysis, strategies are developed for each of the four levels, with additional initiatives which can contribute to the long-term education plan.

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Figure 1
Reorganized Regional, District and Area Office Locations

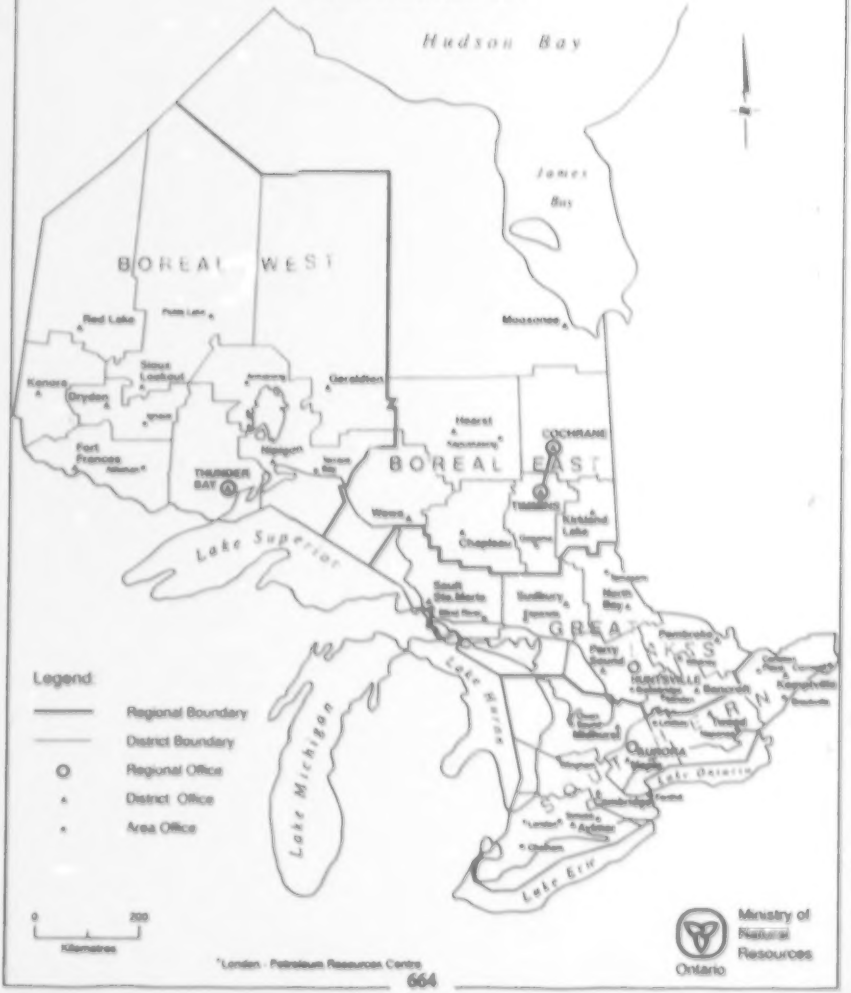


Figure 2
Schematic Diagram Showing Four Levels of Administrative Hierarchy

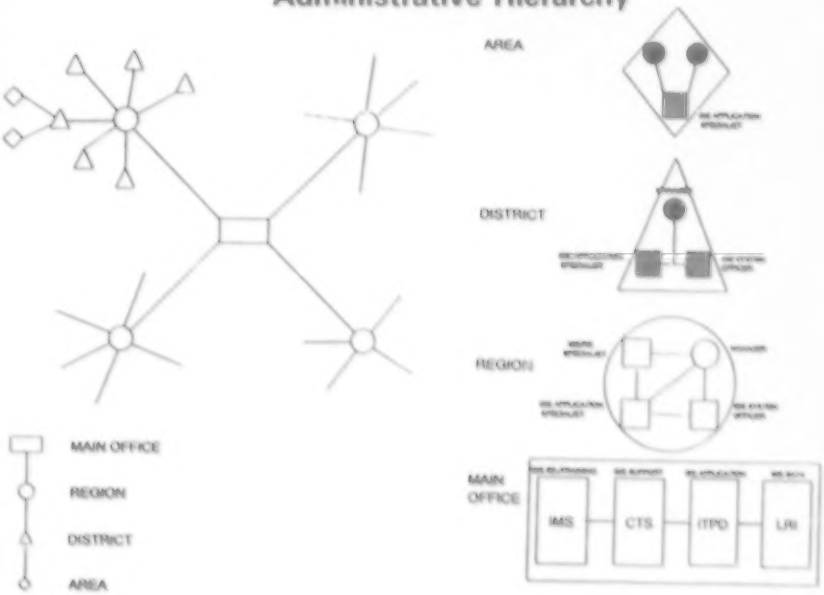
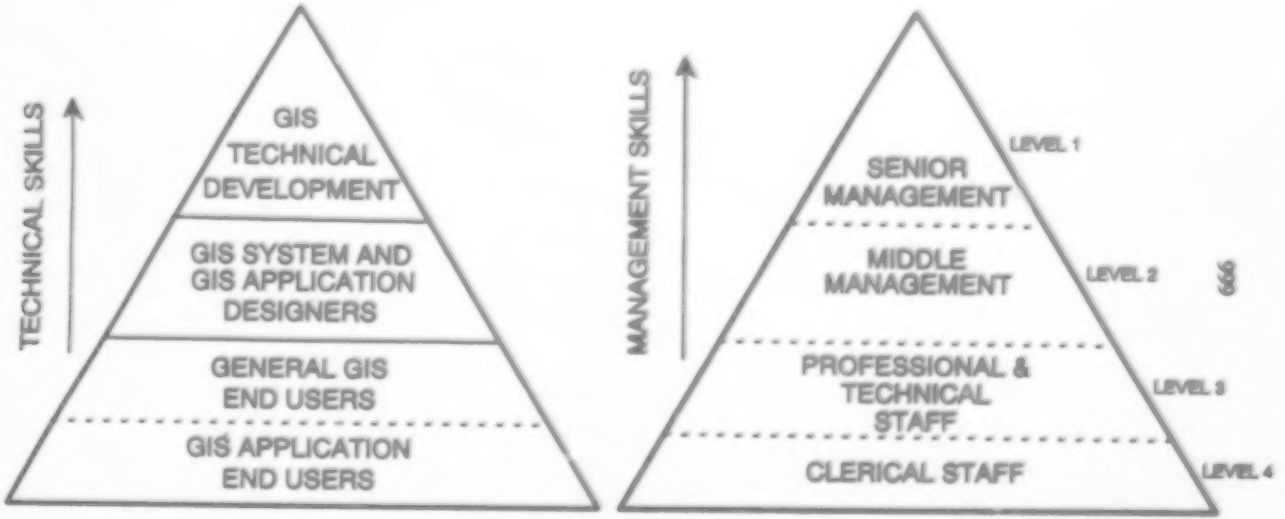


FIGURE 3.

STRATIFICATION OF GIS TECHNICAL & MANAGEMENT SKILLS



ADMINISTRATIVE UNITS AND THEIR FEEDBACK

TABLE 1.

	MAIN OFFICE	REGION	DISTRICT	AREA
NUMBER	1	4	27	113

GEOGRAPHIC DIVISION OF MANAGEMENT SKILLS

TABLE 2.

MAIN OFFICE	REGION	DISTRICT	LEVEL
ADM, Director	Director	-	1
Section Manager	Regional Manager	District Manager	2a
Project Manager	Project Manager	Area Manager	2b
← Professional and Technical Staff →			3
← Clerical Staff →			4

GEOGRAPHIC DIVISION OF TECHNICAL SKILLS

TABLE 3.

TECHNICAL SKILLS	GEOGRAPHIC UNIT		
	MAIN OFFICE	REGION	DISTRICT
GIS hardware/software support.	CTS	GISO	GISO
GIS Analysis/Design Programming.	ITPD / LRI	GIS / RS	GISAS
GIS Training.	IMS / ITPD	RTO	-

DEFINITIONS

CTS: Computer and Telecommunication Services Branch.
ITPD: Information Technology Planning & Development Branch.
LRI: Land Resources Inventory Branch.
IMS: Information Management Services Branch.

GISO: Geographic Information Systems Officer.
GIS / RS: Geographic Information Systems & Remote Sensing Specialist.
GISAS: Geographic Information System Application Specialist.
RTO: Regional Training Officer.

IACG Sub-Committee #2
Data Communications and Networking
1991/92 Activities Report

by
Michael J. Casey
Chairman

1. Priority Issues for 91/92

As part of its 90/91 work plan, the Data Communications and Networking Sub-Committee (#2) of the IACG conducted a study to assess the potential of data communications technology to respond to the needs of the federal GIS community. The two major objectives of this study were:

- to assess the potential of communications technology to respond to the needs of the GIS community within the federal government and
- to stimulate any appropriate action stemming from this assessment.

The work was carried out under contract by the IDON Corporation who conducted an extensive dialog with officials from seven different federal agencies active in the field of geomatics. The final report received a wide circulation within the IACG including a précis in the IACG Newsletter. The Report concluded that:

With regard to the first objective, the majority of those consulted believe that:

- communications technology can,*in the longer term,* respond to the needs of the GIS community within the federal government;
- communications technology can,*in the shorter term,* do little to respond to the needs of the GIS community within the federal government.

The concern that little can be done in the shorter term is a reflection of their perceptions that

- government departments that could use GIS networking now do not know enough about its advantages to demand it;
- departments who know the importance and utility of GIS systems do not yet realize the importance of GIS networking.

- departmental officials responsible for creating GIS databases do not have a mandate to accommodate the needs of other departments for information sharing (i.e., networking).

To address these short-term concerns and longer-term issues, recommendations were made based on two important assumptions:

- that the process must begin now to facilitate the networking and telecommunications of GIS data because, without proper guidelines, this process will become increasingly unmanageable as the installed base of GIS systems expands.
- that technology, in this case telecommunications technology, can be used to facilitate the networking of GIS systems, thus enabling federal departments to co-operate for long term benefits.

That being the case the Sub-Committee planned a two-phased approach to the promotion of GIS Networking: firstly to continue the dialog between similar agencies in government who have an existing need or perceive a future need to share spatial data and secondly, to carry out a pilot project whereby users could tap into the GIS Survey results remotely. These two items became the central objectives behind the Sub-Committees work.

2. Implementation of Network Access to IACG Survey of Government GIS Databases

One of the primary recommendations of the "Federal Geographic Information Systems (GIS) Networks Requirements Study" was to

"... provide telecommunications/computer access to the soon-to-be-completed survey on federal GIS databases and work with other federal departments to ensure it is kept current."

The Sub-Committee began the process for implementing this recommendation and after much discussion derived the following Project Outline. Unfortunately due to funding limitations the work was not initiated and, subject to funding approval from the Main IACG Committee, is due for implementation at the beginning of the new FY.

- ***The Implementation and Operation of an On-Line GIS Directory Access System***

1. Background:
   The GIS Network Study commissioned by the IACG recommended that the first step in the progression to networking of GIS data bases is the development of an on-line directory system and furthermore that the directory content should be taken from the IACG data base survey, the Northern Information Network or both. Such a system would fulfill several important objectives:

   - provide the first example of networking GIS information
   - provide the means of distributing the GIS Data Base Inventory
   - provide a test base for design of appropriate directory data format
   - provide a demonstration of on-line directory and networking capabilities
   - stimulus and potential model for standards in the field
   - stimulus for the creation of further directories
   - stimulus for the creation of greater demand to access the material in the GIS databases

   The contents will also include the directory available from the DIAND Northern Information Network (NIN).

2. Project Objective:
   The objective of this Project is to have an On-Line GIS Directory Access System implemented and running in demonstration mode at the GIS '92 Conference in March '92. **(Note: Funding limitations prevented this Objective from being achieved.)** Depending on funding available the system would continue to be operated for an additional period into the 1992/93 Fiscal Year. The Contractor will be responsible for the implementation, data base loading and operation of the system and provide a Final Report documenting the activity.

3. Statement of Work:
   The contractor will perform the following work:

   a) Research and Analysis Phase
      The following research work will be undertaken prior to the delivery of a interim report which will lay out the basic design of the system. This report will be given at Progress Review Meeting #1.

      Determine User Requirements by conducting interviews with:

      the developers of the IACG Data Base

      candidate users in both public and private sectors

      the appropriate IACG personnel

      users of similar systems (e.g. NIN, FEARO, StatsCan, NAIS, MEDS, COWLIS, ...)

      Determine Hardware and Software requirements for the system in order to meet the following specifications:

      use existing NIN GIS directory standard

      single-user, single-line access, available anywhere across Canada at

reasonable cost

open access permitted to users with standard terminals (e.g. PC/modem)

gather operating statistics such as: accesses per day, time of access per call, retrieval rate, busy signals per day, ...

provide users with a questionnaire regarding level of service required/provided, location of user, ease-of-use, willingness-to-pay, ...

notification of changes in the data base directory

on-line updating to privileged users

automatic time-outs

b) Development Phase
The system as approved at the Progress Review Meeting will be developed according to the agreed upon specifications. The system will be demonstrated at Progress Review Meeting #2. Acceptance of the system will complete this phase of the contract.

c) Operation Phase
Operations are scheduled to commence two weeks prior to the GIS'92 Conference (March 23-27,'92) and continue through the Conference and for a one month period thereafter. An option for continuing the network beyond this date is possible.

d) Reporting Phase
Upon completion of the Operation Phase of the contract the contractor will prepare a Final Report to be presented at a seminar dedicated to a review of the project. The Report will highlight conclusions drawn from the network operations and recommendations for a next generation system.

4. Deliverables
   a) Implementation and operation (incl. system support and maintenance) of the system for the duration of the Operation Phase
   b) Final Report
   c) Concluding Seminar
5. Cost Proposal
   In preparing a Proposal bidders should keep the following items in mind:

• The Proposal should be prepared with an option to carry on the Operation Phase beyond the GIS'92 Conference. A User-Pay option should be considered.

• The Proposal should offer options in terms of contractor-supplied items vs. Government-supplied items. E.g. site location, computer and networking hardware and software, phone lines, etc.

• The Proposal should make particular reference to System Maintenance and System Support

• The Directory will have to be updated at regular intervals. The Proposal should provide costing options dependent upon update frequency.

• The proposal should include options to provide a networking service available at equitable rates anywhere in Canada. Options for access from remote or frontier settlements should also be included.

3. References

"A Federal Geographic Information Systems (GIS) Networks Requirements Study", a report produced by IDON Inc., March, 1991

IACG Newsletter, Summer, 1991

INTER-AGENCY COMMITTEE ON GEOMATICS DATA DISSEMINATION AND GOVERNMENT DATA BASES SUB-COMMITTEE SUMMARY REPORT ON ACTIVITIES

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ABSTRACT

The Data Dissemination and Government Data Bases working group is a subcommittee of the Inter-Agency Committee on Geomatics (IACG), which was formed to promote and foster cooperation among federal government agencies. This working group has had a successful year in accomplishing it's designated tasks in the 1991/1992 fiscal year including: producing one issue of the Federal Geomatics Bulletin and disseminating the report on a survey of federal geomatics data bases. This paper gives a summary report of the ongoing activities including a list of the working group members, the contents of the Federal Geomatics Bulletin and an overview of the data base survey.

COMITÉ MIXTE DES ORGANISMES INTÉRESSÉS À LA GÉOMATIQUE SOUS-COMITÉ SUR LA DIFFUSION DES DONNÉES ET BASES DE DONNÉES DU GOUVERNEMENT RAPPORT DES ACTIVITÉS

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RÉSUMÉ

Le Comité sur la diffusion des données et bases de données du gouvernement est un sous-comité du Comité mixte des organismes intéressés à la géomatique (CMOIG) qui a été créé dans le but de

promouvoir et d'encourager la collaboration des organismes du gouvernement fédéral. Ce Comité a eu beaucoup de succès dans l'accomplissement des tâches qui lui ont été assignées au cours de l'année financière 1991-1992, c'est-à-dire la production de *La géomatique au Canada* et la distribution d'une étude des bases de données géomatiques au sein du gouvernement fédéral. Cette communication présente un rapport sommaire des travaux en cours, une liste des membres du comité, le contenu de *La géomatique au Canada* ainsi qu'une vue d'ensemble de l'étude des bases de données.

INTRODUCTION

The Data Dissemination and Government Data Bases working group of the Inter-Agency Committee on Geomatics (IACG) was assigned the following tasks.

1) To identify and report on geomatics activities of federal government agencies (including an index of existing data bases).

2) To produce and disseminate records of IACG discussions, decisions and achievements, including the publication of a federal geomatics newsletter.

The working group has been very active in working on these tasks and quite a lot of progress has been made in both of these areas.

MEMBERS

The Government data bases working group has many active members. The following list gives the members names, their affiliation and any extra duties or other sub-committee activities, which the member is active in.

Name	Affiliation	Duties
Gordon Plunkett	EMR/GISD	Chairman
Daniel Clavet	EMR/CCG	Secretary
Richard Boudreau	EMR/CCRS	
David Brown	National Archives	
Murray Cameron	STC/EWAD	
Martine Couture	EMR/GISD	
Brian Cromie	EMR/GSD	FGB Editorial Board
Dave Ellwood	EMR/GSC	FGB Editorial Board
Terry Fisher	EMR/CCRS	
Rejean Fontaine	STC/Geography	

Brian Haddon	Forestry Canada	Database Survey
Valerie Hume	DIAND	
Peter Kielland	F&O/CHS	
Dick MacDougall	FAO/CHS	Database Survey
Nick Mosienko	MOT	
Jeff Murray	National Archives	
Stefan Palko	EMR/GISD	
Mario Piamonte	EMR/CCM	
Jean-Lois Scantland	Environment Canada	
Joel Yan	STC/Geography	FGB Editorial Board

ACTIVITIES

The subgroup has had many official meetings in fiscal year 1991/1992 with numerous other meetings, on specific matters. The major activities of the group are the newsletter and the data base survey questionnaire.

FEDERAL GEOMATICS BULLETIN

The Federal Geomatics Bulletin is intended as a vehicle for the communication of information on geomatics activities within the Canadian federal government. It is published several times a year by the Inter-Agency Committee on Geomatics and articles pertain to the methods, procedures and technology associated with systems for the collection, manipulation, display and dissemination of geographically-referenced digital data.

The editorial board for the Federal Geomatics Bulletin consists of Gordon Plunkett (EMR/GISD), Brian Cromie (EMR/GSD), David Ellwood (EMR/GSC), Stefan Palko (EMR/GISD), Martine Couture (EMR/GISD) and Joel Yan (Statistics Canada). The GIS Division within the Surveys, Mapping and Remote Sensing Sector of EMR continues to provide the support for the creation and distribution of the FGB. Barbara McAulay (EMR/CIDC) provides editorial assistance and production support. Translation is provided by the Secretary of State. Additional french technical editing is provided by Diane Blondin (EMR/CIDC).

The print run for the Federal Geomatics Bulletin (FGB) continues to be 8000 copies and the number of pages was increased to 16. Articles selected for issue Volume 3 Number 1 (Spring 1991) of the FGB were as follows:

The Census is Coming
Development of Interchange Standards Evaluation Criteria
EMR establishes Geomatics Information Publishing System
GIS Conference - An Enormous Success
Conservation and Protection Develops GIS Management Strategy
A survey of Ocean Information Systems was undertaken
A soviet trade delegation visits Canada
Statistics Canada develops census cartography course
A Policy on the Management of Information Technology is released
IACG Completes Federal Networks Requirements Study
Postal Code Conversion File
SMRSS announces an Electronic Information Distribution Policy
CISM/CRSS 91 Conference
Canada Assists in Gulf Oil Spill Disaster
Inventory of Federal Geomatics Data Available
A Revolution in Positional Technology
What is Geomatics?
Test Topographic Map Produced Using Satellite Data
Digital Chart of the World Prototype 4 Demonstration
GIS Calendar of Events

Production problems with the Bulletin have been corrected through the allocation of part of a person year to the production of the Bulletin. In future, the bulletin should be produced on a more systematic schedule. The seventh issue of the bulletin, Volume 3, Number 2 (Winter 1992) is currently in production and contains the following articles:

What is Geomatics?
The 1992 Canadian Conference on GIS
GIS Calendar of Events
Committee on Geomatics charts course for Canadian Standard
New IACG Chairman
IACG Steering Committee Approves Activities
Data Base Survey Report Available
Resource and Environmental GIS Data Base for East Coast Regions
GIS applications in Federal Electoral System
International Cooperation in Geomatics
New Edition of Mineral Map Released
Toponymic Data Base Changes it's name
Mineral Potential Mapping with GIS
GIS at the National Archives
Northern Information Network
EMR and Carleton University Cooperate in GIS

EMR and Laval University Cooperate in GIS
SMRSS Contracting out Bulletin Available
Revised NTDB Standards and Specifications
Geoinfo, 25th Issue
Environmental Information System from Statistics Canada
Federal Government Data Bases for Environmental Reporting
NSERC Research Grants Awarded
SMRSS gets more business like
IACG Seminar Series

A subscription request form for the Federal Geomatics Bulletin is available and has been distributed at conferences and exhibitions. Anyone wishing to receive the bulletin should send a written request to:

Federal Geomatics Bulletin
Secretariat, IACG
Geographic Information Systems Division
Energy, Mines and Resources Canada
615 Booth Street
Ottawa, Ontario
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DATA BASE SURVEY

The working group completed a survey of federal government geomatics data holdings. The survey results are an invaluable source of information for the many users who require GIS data for their analysis. Also, by knowing the existence of significant datasets, duplication of data collection can be minimized.

The working group drafted a list of information to be collected, administered the effort on the survey and evaluated the resulting report. The survey was conducted through the completion of a questionnaire by a large number of selected agencies. The following criteria was applied for dataset inclusion:

1) the dataset must be in the possession of a federal government department or agency;

2) the dataset must be descriptive of some part of Canada;

3) the dataset must contain an element that has a direct reference to a coordinate framework (Latitude-Longitude for example);

4) the dataset must be at a scale smaller than 1:500;

5) the dataset must be in digital form now, or there must be plans to convert the dataset to digital form within the next 10 years.

The number of questionnaires completed was greater than anticipated. A total of 314 responses from 35 agencies were received and the summary by department is as follows:

Department	Number of Agencies	Number of Datasets
Environment Canada	6	156
Energy, Mines and Resources Canada	9	61
Agriculture Canada	2	32
Forestry Canada	2	15
National Archives of Canada	1	13
Statistics Canada	1	7
Fisheries and Oceans	1	7
Indian and Northern Affairs	1	5
Atomic Energy of Canada	1	4
Transport Canada	2	2
Department of National Defence	1	3
National Capital Commission	1	2
Others	7	7
Totals	35	314

Information on each dataset such as identification, description, availability, structure and applications was collected, verified and entered into the survey results database. Indexes on dataset name, acronym, agency, category, type and coverage were produced with additional analysis of the results database ongoing.

Some significant conclusions of the report on the survey are as follows:

1) There appears to be considerable potential for the exchange and use of digital geographically referenced datasets. There seems to be little evidence of duplicate data collection or ignorance of the activities of other federal agencies.

2) There is evidence of a spread in the use of digital datasets within the federal government. In particular, there appears to be an increasing emphasis on special purpose datasets.

3) Most agencies store their digital data in de facto standard formats, largely established by vendors.

4) Digital data continues to be most common in domains where the geographical distributions are inherently stable through time, and less common where phenomena are strongly time dependent.

5) Three dimensional data appears to be in limited use, even in applications where the vertical dimension may be important.

6) The availability of digital data is strongly influenced by environmental and resource management concerns. There appears to be little progress in developing digital datasets with social, economic, health, industrial or other themes related to human activities.

The summary report entitled *"Report on the current status and Trends in Federal Digital Geographic Data in Canada"* has been distributed and the working group is currently studying alternatives for the maintenance and update of the database. For a copy of the report complete the form given in the Appendix and mail to:

Secretariat, IACG
Geographic Information Systems Division
Energy, Mines and Resources Canada
615 Booth Street, Room 753
Ottawa, Ontario
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SUMMARY

The government data bases subcommittee has been active and has produced one issue of the Federal Geomatics Bulletin, with plans for future issues in the works. The survey of the government data bases is available for dissemination. The working group plans to be active in coordinating the data base directories that are being developed in other government agencies. Also the group is initiating a contract for one update of the existing directory.

BIBLIOGRAPHY AND REFERENCES

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Plunkett, Gordon W; March 1990; "Inter-Agency Committee on Geomatics, Government Data Bases Sub-Committee, Summary Report on Activities"; Proceedings of the National Conference, GIS for the 1990s; Ottawa, Ontario; Canadian Institute of Surveying and Mapping; pp 1266-1269.

Plunkett, Gordon W; March 1991; "Inter-Agency Committee on Geomatics, Government Data Bases Sub-Committee, Summary Report on Activities"; Proceedings of the Canadian Conference on GIS; Ottawa, Ontario; Canadian Institute of Surveying and Mapping; pp 1266-1269.

Plunkett, Gordon W; August 1991; "Federal Coordination Activities Summarized"; GIS World, Vol 4, No 5; pp 39-41.

Inter-Agency Committee on Geomatics (IACG); "Report on Current Status and Trends in Federal Digital Geographic Data in Canada; Final Report"; May, 1991.

Inter - Agency Committee on Geomatics
Digital Database Of Questionnaires
Order Form

Comitée Mixte des Organismes Intéressés à la Géomatique
Bon de Commandes Pour la Répétoire des Jeux de Données Sous Forme Numérique

Name / Nom:_____
Title / Titre:_____
Department / Département:_____
Division / Division:_____
Companie / Compagnie:_____
Street / Rue:_____
City / Ville:_____
Province / Province:_____
Country / Pays:_____
Postal Code / Code Postal:_____
Phone Number / Numéro de Téléphone:_____

☐ I.B.M. ASCII Format (3.5" diskette)
☐ I.B.M. DBase IIIplus Format (3.5" diskette)
☐ Macintosh ASCII Format (3.5" diskette)

Comments / Commentaires:_____
_____
_____
_____

Send To:

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Inter-Agency Committee on Geomatics
Sub-Committee #4 - Geomatic Standards

Timothy Evangelatos - Chairman
Canadian Hydrographic Service (DFO)
Joel Yan
Geocartographics Division (SC)
Dave Brown
Cartographic and Audio Visual Division (NA)
Jamie Hillman
Canadian General Standards Board
Peter Brimacombe
Land Resources Research Division (AC)
Gordon Plunkett
Geo. Information Systems Division (EMR)

Francois Masse - Secretary
Canada Centre for Geomatics (EMR)
Louiselle St. Laurent
Geo. Information Systems Division (EMR)
David McKellar
Directorate of Cartography (DND)
Patrick Lloyd
Geographic Services Division (EMR)
David Armstrong
Topographic Mapping Division (EMR)
Charles Farah
Client Services Directorate (I&NA)

1991 Report:

1.0 Canadian Standards Activities:

1.1 The Canadian General Standards Board (CGSB-COG): The Committee On Geomatics was founded by IACG Sub-Committee #4 in 1989, in order to provide an open forum in which all sectors of the Canadian Geomatics Community could participate and have a voice in the selection and/or development of Canadian Standards. The initial phase of the consensus process has now been completed.

Working Groups 1 (Data Encapsulation) and 2 (Data Modelling) of the Committee on Geomatics completed an evaluation of the seven exchange specifications and recommended that SAIF, STDS and DIGEST be considered. The specifications considered were (Latour 1991):

CCOGIF - Developed under the Canadian Council On Geomatics (formerly Canadian Council for Surveying and Mapping) this format is being used for the distribution of EMR's topographical data.

DIGEST - Developed by 11 nations to satisfy military needs, but now being adopted by civilian users as well. Its use in the Digital Chart of the World will aid acceptance. Version 1.0 is approved and in use.

DX90 - Developed under the auspices of the International Hydrographic Organization (IHO)to meet requirements for distribution of both paper and electronic chart information. A proposed Version 1.0 is now being evaluated and the standard may obtain official approval in May 1992.

MACDIF/MDIF - First spatial exchange specifications to be based upon OSI (Opens Systems Interconnection); developed by the Ontario Ministry of Natural Resources and the Federal Government. Many of the ideas have being incorporated in either DIGEST and SAIF.

SAIF - Proposed by the B.C Ministry of Crown Land's, it was designed to satisfy all of the criteria, compiled by CGSB-COG Working Group 2, for a Canadian standard. Funds are being sought for it's development. Approximately $1,000,000 over 3 to 5 years are required to develop it.

SDTS - Developed in the U.S., it will soon be officially approved by the National Institute for Science and Technology as a Federal Information Processing

Standard (FIPS). Several nations have indicated that they may adopt it as heir own national standard.

After much discussion the CGSB's Committee on Geomatics agreed that[1]
"The CGSB-COG should propose and support a draft Canadian Geographic Interchange Standard (CGIS) based on SAIF."

"The CGSB-COG should participate actively and contribute to international standardization activities."

To implement these recommendations it was decided to replace Working Groups 1, 2, and 3 (Feature Classification), with three new Working Groups as follows:

Working Group 5: To be responsible for liaising with international geomatics standardization activities.

Working Group 6: To be responsible for developing a national strategy to raise resources to develop and implement SAIF in conjunction with other key players such as the Canada Centre of Geomatics and the Inter-Agency Committee on Geomatics. This group would also examine the possibility of establishing a secretariat to coordinate national standards activities.

Working Group 7: This group would be responsible for populating the feature identification model which has been defined by Working Group 3.

Standards for describing datasets and for creating data directories of machine readable geomatic datasets are being sought by Working group 4. This group is also seeking more individuals willing to share its task.

The IACG Sub-Committee #4 provides approximately $25,000 to the cover the costs of CGSB activities in support of the Committee On Geomatics and is active in the COG Working Groups as well as participating in the main committee meetings. In addition the Chairperson of the Inter-Agency Subcommittee #4 is also a member of a proposed Executive Standards Committee.

1.2 Treasury Board Information Technology Standards (TBITS) Program: The IACG Subcommittee #4 has been used as a nucleus to form a working group under Treasury Board. This new group which met twice in 1991 will not duplicate efforts of other groups. Its purpose is to support TB's role of providing strategic directions for the management of information technology, to provide mechanisms for the approval and implementation of federal government standards, to officially coordinate the government's position on geomatic standards, ensure the dissemination to all affected institutions, and ensure the participation of appropriate government agencies in both national and international efforts.

1.3 GIS 91 Standards Workshop: For the third time a workshop on standards was organized in conjunction with the Canadian GIS Conference. The timing of the workshop was good since the evaluation of seven potential standards was close to completion and formed the basis for presentations from the various spokes-persons or champions of the

[1] Minutes of the 5th Meeting of the Committee On Geomatics held in Ottawa on the 26 June 1991.

seven specifications. Lively discussions were held and participants were able to obtain technical details on the various specifications.

2.0 International: Standards Activities:

2.1 International Cartographic Association: The working group on Digital Cartographic Transfer Standards published a monograph (Moellering 1991) on the current international status of standards development among member nations. The group which meets once a year is now preparing a set of criteria with which the various national standards can be evaluated and compared. This is meant to be an aid to help others in understanding the standards and is not intended to pick "winners". The list of criteria will be finalized in 1992 and the standards comparison will be published in a second monograph by May 1993.

Digital Geographic Information Working Group (DGIWG): Established in 1983, this is a NATO derived group, with a membership of 11 nations and is the most active group working toward international geomatic standards. Although the focus has been on military applications, where many of the standards have been implemented, the group's work is now receiving a lot of attention from the civilian geomatics sector. Version 1.0 (DIGEST 1991) incorporates three compatible forms for data encoding these are: ISO 8211 (also used by STDS) for exchange between non-communicating parties; ISO 8824/25 of OSI telecommunication exchange (Initially used in MACDIF/MDIF) and a relational implementation also used for the Digital Chart of the World (DCW) Project (Hum and St. Laurent 1991).

International Hydrographic Organization: This is an association of 57 hydrographic offices of maritime nations with a focus for standardizing nautical charts and associated publications. The IHO has taken a lead role in developing standards for the emerging electronic chart display and information systems (ECDIS). SP-57, the proposed specification for data interchange consists of an ISO 8211 based exchange mechanism (DX90), an "Object-Catalogue" which describes the navigational objects and their attributes, and a set of digitizing rules (IHO 1991).

Canada is represented on all three group by members of the IACG Sub-Committee #4.

3.0 Work Plan for 91/92:

As in the past, members are hard pressed to find time to spend on Sub-Committee activities. As members are also involved in the other CGSB working groups, the S-C #4 will limit the number of its meetings to 4 per year. The focus of standards development has been on exchange mechanisms but many other areas that also need standards are being neglected and therefore the group will explore some of the other needs. The proposed program of effort for the new year are:

1. Review Terms of Reference to include work of IACG Sub-Committee #1 which was dissolved in 1991.
   (Members of S-C #1 have been invited to join S-C #4)
2. Active participation in CGSB-COG's Working Groups:
   W.G. 4 - Data Directories
   W.G. 5 - International Liaison.
   W.G. 6 - SAIF National Implementation Strategy
   W.G. 7 - Population of the Feature Identification Model / Codification Scheme.

3. Organize Standards Workshop in conjunction with GIS 92.
4. Increase liaison with counterparts in the U.S. which appear to be making more progress in implementing and using a single standard.
5. Develop a better vision upon which to base the committee's activities.
6. Provide direction to the CGSB-COG and the Treasury Board Working Group.
7. Possible workshops on Data Quality and Descriptive Cataloguing of Geomatic data Sets.
8. Possible survey on IACG User needs for Geomatic Standards by interviewing key staff of memebr agencies.

4.0 Conclusions: Although consensus was achieved to support the development of a unique and progressive Canadian standard (i.e. SAIF), it may be difficult to obtain the resources to develop and implement this specification. NIST approval of the American SDTS standard and commitment to its use by American Federal Government agencies means that GIS vendors will definitely provide and support the generation of data in SDTS. This might make SDTS the format of choice for some Canadians. Similarly, the CD-ROM's of the "Digital Chart of the World" will be available in early 1992, apparently bundled with the DCW source software, and for some users this will be a convenient format. It is clear that users' hopes for a single format will not materialize in the foreseeable future.

5.0 References:

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Videodisk Mapping Production Program

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Abstract

Video disk mapping is rapidly gaining acceptance among several government departments as a low cost map display background capability which can provide many of the information coordination functions of a GIS. EMR's Products and Services Division, in cooperation with DND and other government agencies, is sponsoring and coordinating the production of six video laser disks which, when completed, will provide complete 1:250,000 scale coverage (and smaller) of Canada. The contents of these disks, which are being funded largely by the National Search and Rescue Secretariat, will include topographic maps aeronautical and nautical charts. This paper is a report on the current status and future development for this program.

Programme de cartographie sur vidéodisque

RÉSUMÉ

La cartographie sur vidéodisque acquiert rapidement de la popularité auprès de plusieurs ministères gouvernementaux, car il s'agit d'un moyen peu coûteux de produire des fonds de carte, permettant d'assurer de nombreuses fonctions de coordination d'un SIG. La Division des produits et services d'Énergie, Mines et Ressources, en collaboration avec le ministère de la Défense nationale et d'autres organismes gouvernementaux, parrainent et coordonnent la production de six vidéodisques au laser qui offriront une couverture complète du Canada à une échelle de 1/250 000 (ou à une échelle plus petite). Ces disques, dont la production est financée, dans une large mesure, par le Secrétariat national de Recherche et sauvetage, comporteront des cartes topographiques, aéronautiques et marines. Ce rapport porte sur l'état actuel et l'évolution future du programme.

OCT-TREE REPRESENTATION OF GEOLOGICAL STRUCTURES for a THREE-DIMENSIONAL GIS

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ABSTRACT

A fundamental aspect of any spatial information system is the data structure used to model and store the data. An ideal data structure for storing geoscientific information must provide fast access to the data in both internal and external computer memory. The data structure should be capable of maintaining the topological relationships in the data despite the inherent complexities encountered when dealing with geoscientific representations. Of course, geological information is usually three-dimensional, which adds to the complexity of the data and increases the storage requirements. Data structures based on recursive decomposition modelling seem to offer the best method for handling geoscientific representations, but there are many alternatives. The oct-tree is a recursive decomposition data structure which seems to be particularly well suited for storing geoscientific data. A test data set of subsurface geological information from the Cherhill area of Alberta was used to develop and compare a number of versions of oct-tree data structures including regular oct-trees, DF-trees and linear oct-trees.

RÉSUMÉ

Un élément fondamental de tout système d'information spatiale est la structure des données employée pour la modélisation et le stockage des renseignements. Une structure de données idéale pour le stockage des renseignements portant sur les caractéristiques géologiques doit permettre un accès rapide tant aux données de la mémoire interne que celles de la mémoire externe de l'ordinateur. La structure doit permettre de conserver les relations topologiques des données en dépit des complexités inhérentes aux représentations géoscientifiques. Les renseignements géologiques sont habituellement de nature tridimensionnelle, d'où la complexité accrue des données et la place plus importante que celles-ci occupent en mémoire. Les structures de données fondées sur une décomposition récursive semblent offrir le meilleur moyen de traiter les représentations géoscientifiques, mais il existe de nombreuses autres méthodes pouvant remplacer ce type de structure. L'arbre octo constitue une structure de données à décomposition récursive qui semble se prêter tout à fait au stockage de données géoscientifiques tridimensionnelles. On s'est servi d'un jeu d'essai de données sur la géologie de subsurface des environs de Cherhill, en Alberta, pour mettre au point et mettre à l'épreuve un certain nombre d'autres structures de données à arbre octo, dont des arbres octo réguliers, des arbres DF et des arbres octo linéaires.

INTRODUCTION

The representation of geological structures requires large amounts of multi-variate data and complex three-dimensional spatial relationships. For this reason spatial information systems are needed to facilitate the representation and analysis process. A fundamental part of any spatial information system is the structure used to model and store the data. Ideally, a data structure should provide **fast access** to the data and be able to store the data in a **compact manner**. While these ideals tend to oppose one another, a well-balanced compromise may be achieved by using a data structure based on recursive decomposition modelling. This type of data structure offers a number of advantages over other methods for storing three-dimensional information. Expressed in the form of a tree structure, they are particularly well-suited for efficiently storing complex inhomogeneous spatial objects. In addition they support easily implemented and relatively fast geoprocessing algorithms, and they readily allow the retrieval of spatial data subsets. There are a number of optional data storage techniques based on recursive decomposition modelling. The principal difference between them involves the degree to which their tree structures are explicitly stored, which in turn affects their processing speed and representational efficiency.

OCT-TREE DATA STRUCTURES

Recursive decomposition modelling is a technique used to represent an object by repeatedly dividing the space containing the object until the resulting subdivisions are either full or empty with respect to the object, or a desired level of resolution has been reached. The quadtree is a tree structure used to store two-dimensional recursive decompositions where the subdivision is into four equally sized blocks at each level of the decomposition. Quad-trees have been adapted for use in storing multi-dimensional data and are referred to as k-d trees in their generalized form (Jackins and Tanimoto 1983). Various spellings have been used for the three-dimensional version of the quadtree including oct-tree, octtree, and octree. We have adopted the first of these - "oct-tree". The original concept of the oct-tree was developed independently by many researchers including Jackins and Tanimoto (1980) and Meagher (1982).

In an oct-tree structure the object to be stored is contained in the universe which is represented by the root node. Each non-uniform node, beginning with the root node, is subdivided into eight equal-sized children called octants. Recursive subdivision continues until the value of an octant is either full or empty with regard to the attribute in question, or the desired level of resolution has been reached. The smallest blocks, sometimes called "voxels", in parallel with the two dimensional "pixel", are a function of the maximum resolution and are the fundamental constituents of the decomposition. Nodes of the resulting oct-tree correspond to the blocks of the associated decomposition. End, or lowest level, nodes are referred to as leaf nodes and ancestor nodes are referred to as non-leaf or grey nodes. In a binary oct-tree leaf nodes are either full (black) or empty (white) with respect to the object being stored. Multi-variate data may be stored by assigning attribute values to the leaf nodes, sometimes referred to as a "coloured" oct-tree.

A major advantage of the oct-tree compared to other three dimensional data storage techniques is its ability to adapt to inhomogeneous data. The degree of subdivision necessary to store a particular region of an object is a function of the boundary complexity of that region. Large blocks are used to represent uniform areas and small blocks are used to model complex areas (Meagher 1982). In effect, the oct-tree adapts to the data in an efficient manner so that the largest portion of the data structure is used to store the most complex areas of the representation. It is this "divide and conquer" principal upon which the oct-tree structure is based that makes the oct-tree particularly well-suited for storing extremely complex representations, such as, those typical of geological sub-surface structures, and leads to high relative representational efficiency.

Many of the functional requirements of a geoscientific spatial information system such as Boolean operations, display operations and connected component labelling are easily implemented using an oct-tree data structure. The spatial addressability and ordered nature of the tree structure allows most of these operations to be implemented as tree traversal algorithms (Chen and Huang 1988), and do not require the explicit expansion of the tree representation into the full set of voxels. In the most general form of the oct-tree, nodes are linked using pointers so that a tree traversal is a matter of following the pointers up or down the tree (Samet 1990a). Although topological relationships are not explicitly stored as part of an oct-tree data structure, they may be derived by applying neighbour finding and connected component algorithms. Nodes which have been determined to be a part of a connected region may be labelled as such within the original oct-tree, or a new separate tree structure can be built for the specific region of interest.

The nodes at any level of an oct-tree structure combined with the nodes of the higher levels of the oct-tree represent the entire object being stored. Consequently, algorithms can operate at a level of the oct-tree appropriate to the task at hand, thereby avoiding the large volumes of data stored in the lower levels of the oct-tree. In this sense, the oct-tree is a variable resolution data structure (Meagher 1982). In addition, it is easy to retrieve only a portion of the tree so that a subset of the data can be selected as needed.

An oct-tree representation may be displayed directly or by first converting it into a surface representation. Direct display methods have an advantage in terms of hidden surface removal because octants closer to the viewer obscure octants behind them, and at most three surfaces or seven corners can be visible from one viewpoint. Thus, hidden surface removal is easily accomplished by visiting nodes in an order determined by the viewing direction (Gargantini et al. 1986). Direct display methods, however, are difficult to render with great realism due to the orthogonal nature of the blocks used to store the representations.

REPRESENTATIONAL EFFICIENCY

The use of some discrete subdivision to represent a continuous object introduces an error, which could be expressed, for instance, by the relative difference between the true volume of the object V_T and the represented volume of the object, V_R . Thus the

representational error could be expressed as:

$$E = (V_T - V_R)/ V_T$$

This error can obviously be reduced to an arbitrarily small level by increasing the representational storage requirements - for instance, by increasing the number of vertices in a triangular plate model, or the number of oct-tree levels in a regular subdivision. The term representational **efficiency** refers to the accuracy of the representation **relative** to the storage requirements. Representational efficiency can be expressed as:

$$R = M_A / M_S$$

where M_S is some measure of the storage required
and M_A is a measure of the accuracy (inverse of error) of the representation.

The goal, of course, is to achieve high accuracy, with minimum storage.

Subdivision to lower oct-tree levels predominantly occurs at the boundary of an object, therefore, the space required to store an object using an oct-tree is a function of the total surface of the boundary as opposed to the volume of space occupied by that object (Samet 1990b). A major drawback of the general, or regular form of the oct-tree is that it requires a large amount of storage space, much of which is overhead associated with the storage of non-leaf nodes. In addition, storage space must be allotted for nine pointers for each non-leaf node. Eight pointers are needed to point to the descendants of a non-leaf node and one pointer is needed to point to its father (Samet 1990a). Sub oct-trees may be used to store a representation divided into maximal blocks which are then stored as a forest of subtrees. The main advantage of the forest concept is that empty areas of a representation are not stored (Jones and Iyengar 1984).

Another technique dispenses with the pointers and stores the oct-tree as a list in the form of a pre-ordered tree traversal. This structure, referred to as a DF-expression, is based on the fact that every non-leaf node has eight children. The tree structure, therefore, may be derived from an ordered list of the nodes (Kawaguchi and Endo 1980).

In a linear oct-tree, pointers, non-leaf nodes and empty nodes are done away with altogether. Each leaf node is assigned a base eight code which locates the node in the tree structure and specifies the path from the root node to the leaf node (Gargantini 1982). Research using linear oct-trees to store geoscientific representations has been reported by Bak and Mill (1989), and Dunstan and Mill (1989). Refer to Figure 1 for an example of a regular oct-tree, a DF-expression and a linear oct-tree.

For a given oct-tree level, the measure of accuracy will depend on the shape of the object represented, particularly the complexity of its surface. The storage required for a given level of accuracy depends only on the choice of tree representation. In very approximate terms (because of the shape dependency), the regular oct-tree requires storage of 9 pointers, the D-F expression about 5 equivalent pointers, and the linear oct-tree about 2. Thus the linear

oct-tree is about 4.5 times more representationally efficient than the general form. Empirical testing with realistic data sets is required to verify these approximations, and to compare the representational efficiencies with the relative speed of desired spatial processing.

THE TEST DATA SET

A test data set consisting of information gathered from petroleum industry sources was used to evaluate various three-dimensional data structure alternatives. Typical petroleum industry information includes subsurface geological, geochemical, geophysical and reservoir engineering data collected while drilling and evaluating boreholes. The coverage of this kind of data depends upon where the wells were drilled and to what depth, so that the resulting data set is mainly comprised of irregularly dispersed point data. A large amount of information is available from each borehole, therefore, in order to limit the size and complexity of the test data set only key attributes were selected.

An interpolation technique based on the concept of area stealing (Gold 1989) which uses Voronoi polygons was used to model the Cherhill data, and to generate a three-dimensional raster representation of the interpolated data. This was converted into an oct-tree by repeatedly applying a merging algorithm. In this manner, a recursive decomposition data structure in the form of an oct-tree was constructed from the bottom up.

A four township area (townships 55 and 56, ranges 4 and 5 west of the 5th meridian) near Cherhill, Alberta was selected (Figure 2) to serve as a test block. Up to seven subsurface geological zones (Table 1) were picked from each well within the study area by using geophysical well logs. Out of range values were used to flag absent zones and zones not penetrated; otherwise, the height of the top of each zone relative to sea level was determined. A total of 253 wells had been drilled in this four township block as of the time of this study. Stratigraphically, the Cherhill block consists of the Mannville Group, Nordegg Formation and Banff Formation as they are distributed over the four townships. Estimated values have been incorporated into the data set for geological modelling purposes where subsurface control was lacking.

Volumetrically, the study block consists of approximately 100 cubic kilometres of rock. This is a large volume when contrasted with the 2 or 3 metres of vertical resolution which is required for most petroleum exploration and development projects. Added complexity stems from the fact that some of the zones, such as the Nordegg and the Banff porosity are not continuous over the project area. In addition, the boundaries between the zones vary in complexity. Some are smooth while others, the top of the Banff Formation in particular, are highly irregular.

GEOSCIENTIFIC OCT-TREE REPRESENTATION

As described previously, each of the seven zones included in the test data set was individually processed using Gold's area stealing method. The resulting gridded data were combined so that each grid node had seven values associated with it (one for each zone). A merging algorithm was then repeatedly applied to build the oct-tree.

The leaf nodes of the resulting oct-tree can be thought of as a collection of multicoloured blocks of various sizes. There is one colour for each of the seven zones. A representation of the block decomposition for a small sample of the Cherhill oct-tree using three of the seven zones is presented in Figure 3. Larger blocks are found interior to the various zones and smaller blocks define the boundaries between the zones. In this sense, a major portion of the oct-tree is devoted to storing the boundaries. Where a choice must be made between two or more zones present within a voxel, the value of the voxel is determined to be the value of the predominant zone.

For most geological purposes the horizontal resolution can be more coarse than the vertical resolution so that voxels are actually plates rather than cubes. This shape is manifested throughout the oct-tree as the larger blocks are derived from the shape of the smaller blocks. A ratio of approximately 100 metres by 100 metres by 4 metres seems to work well for the size of a voxel, at least for the Cherhill data set. This ratio loosely corresponds to the sheet type morphology of the various rock units and roughly fits the overall shape of the three-dimensional test data block.

CONTINUED RESEARCH

Using the size of the voxel from above and fully dividing the study area into the minimum voxel size blocks results in approximately 1,200,000 voxels. By merging them into an oct-tree, significant data compression is achieved. However, because each octant has nine pointers associated with it, the regular oct-tree carries with it a tremendous amount of data storage overhead. Roughly 10^7 bytes are needed to store the Cherhill regular oct-tree, ie. more than the equivalent explicit voxel representation. If a DF-expression is used, pointers are done away with altogether resulting in a savings on the order of 80% for this data set. Even more savings can be achieved by using a linear oct-tree which does not store non-leaf nodes. Of course, these more austere forms of the oct-tree carry a price in terms of geoprocessing efficiency. Tests are currently being conducted to assess the advantages and disadvantages of various oct-tree forms in terms of representational efficiency vs. the efficiency of geoprocessing and display operations.

CONCLUSIONS

Oct-trees are especially well suited for storing complex and inhomogeneous data. Large volumes can be easily decomposed and merged into oct-trees of reasonable size, yet with acceptable resolution and representational efficiency. Most of the oct-tree data structure is devoted to storing the more complex regions of the space being represented. A plate like shape for the decomposition worked well for modelling the test data set, typical of geological applications. Oct-trees have been found to be easy to display provided highly realistic visualization is not a major concern. Finally, fundamental geoprocessing functions such as subset and geometric operations can be easily implemented using tree traversal routines.

In general, the oct-tree is a data structure which is well suited to storing three-dimensional geoscientific representations.

ACKNOWLEDGEMENTS

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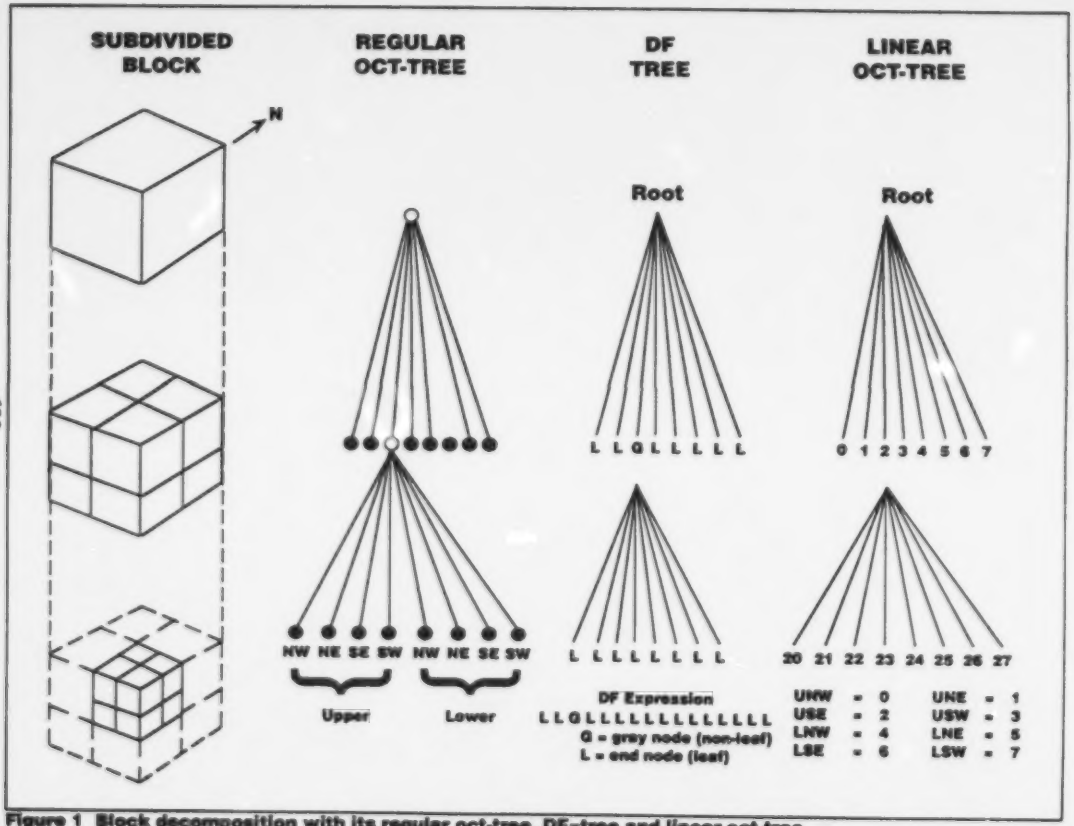

Figure 1 Block decomposition with its regular oct-tree, DF-tree and linear oct-tree

1	Top of the Mannville Group
2	Top of the Glauconitic Formation
3	Top of the Nordegg Formation
4	Top of the Banff Formation
5	Top of the Banff porosity
6	Base of the Banff porosity
7	Top of the Wabamun Formation

Table 1 Statigraphic markers used to define the zones for the Cherhill study

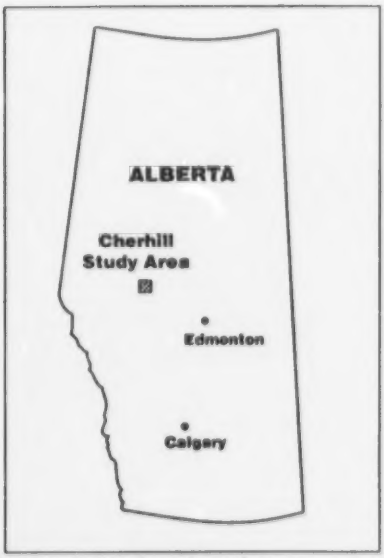

Fig. 2 Study Area Location

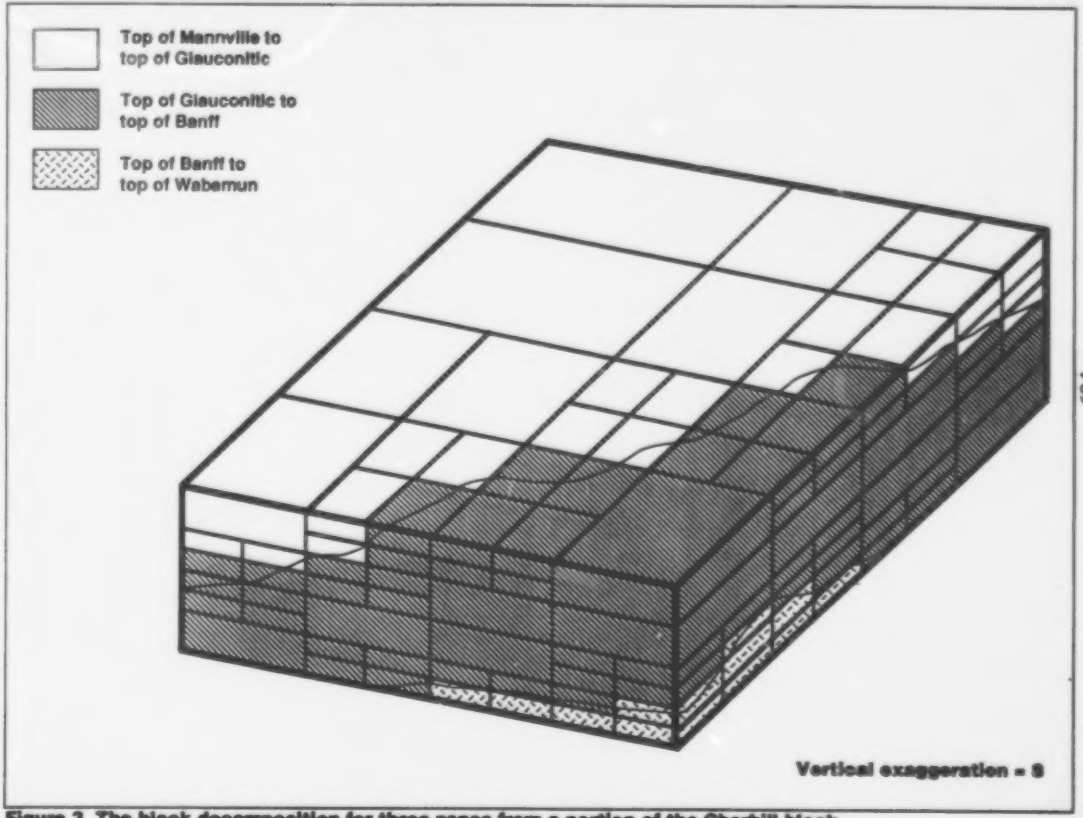

Figure 3 The block decomposition for three zones from a portion of the Cherhill block

BIOGRAPHICAL NOTES

Robert Warford graduated from the University of Tulsa in 1983 with an honours B.Sc. degree in geology. He has since worked for Sullivan and Company as an Exploration Geologist and is currently Manager of Canadian Operations. Recently, he has been engaged in masters level research at the University of Calgary, Department of Surveying Engineering.

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VIDEO DISK MAPPING - AN INTERIM GIS FOR THE CANADIAN MILITARY

by

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ABSTRACT

Since their introduction in 1987 into the Department of National Defence (DND), Video Laser Disks (VLDs) are proving to be a viable alternative to vector/raster based GIS. VLDs provide a cost effective avenue for the military GIS user who wishes to display and analyze geographic data quickly. Over 40 video disk mapping systems have been installed in DND and the demand is still growing. This paper will review the military applications of VLDs and discuss their enormous potential for carrying out the geographic functions needed today.

CARTOGRAPHIE SUR VIDÉODISQUE - SIG PROVISOIRE CHEZ LES MILITAIRES CANADIENS

RÉSUMÉ

On se rend compte que, depuis leur implantation, en 1987, au sein du ministère de la Défense nationale (MDN), les vidéodisques au laser constituent un moyen viable de remplacer les SIG vectoriels ou matriciels. Les vidéodisques représentent, pour les militaires se servant de SIG, un moyen économique d'afficher et d'analyser rapidement des données géographiques. Plus de 40 systèmes de cartographie sur vidéodisque ont été installés au sein du MDN, et la demande ne cesse de croître. Ce document examinera les applications militaires de vidéodisques ainsi que l'immense potentiel que ceux-ci offrent pour obtenir les représentations géographiques requises à l'heure actuelle.

INTRODUCTION

Video disk mapping has become the interim GIS of preference for the Canadian Forces due mainly to its large storage capacity and rapid retrieval, two characteristics critical to any military information systems. Modern geographic information comes in a variety of media ranging from magnetic tapes, video tapes, paper maps, paper prints, overlays and documents. Each of these products requires its own space and procedures for storage and processing. The problem in dealing with this large amount of diverse information can become critical to the military user on the battlefield.

Video disk mapping technology has been applied to this problem of storing and displaying geographic data. Video laser disks (VLDs) can store up to 54,000 frames of pictures on each side and can randomly access any single frame in less than three seconds. VLDs also offer the advantage of being a relatively compact and light medium for storing information. A worldwide database of maps, charts, and imagery, stored on twelve-inch VLDs, provides the military users with a high resolution map display background for various defence applications.

This analogue technology does not mean the end of digital GIS development for the military, but rather constitutes a viable alternative to vector/raster-based GIS until a more populated digital database is available. Nowadays the Canadian Forces deploy and operate around the world and therefore require a solution today to their geographic needs. The potential of video disk mapping has also been ascertained by other nations and VLDs have recently become a standardized product throughout NATO.

VIDEO DISK MAPPING IN NATIONAL DEFENCE

The Department of National Defence (DND) has over 40 video disk mapping systems installed across Canada and the demand is growing. The largest single group of users is Search and Rescue with 25 systems deployed throughout the country in their regional coordination centres. In 1988, the National Search and Rescue Secretariat (NSRS) adopted the video disk technology as a relatively economical means of rapidly locating the position of aircraft and vessels in distress and coordinating their search and rescue operations.

The NSRS has also been the major source of funding for the production of the Canadian series of VLDs. These dual sided disks will contain complete coverage of the Canadian territory (including Greenland) at scales ranging from 1:5,000,000 to 1:250,000 with limited coverage at 1:50,000 for large cities or military training areas. This production program is being directed and coordinated by the Department of Energy, Mines and Resources in cooperation with other federal government departments.

The other significant group of users of video disk mapping in DND is the operations centres at National, Command, and Formation Headquarters across Canada. They use the video disk system to plan, control, and coordinate various military operations in Canada and around the world. They can also interface with real time systems for monitoring events on the video map background or make use of teleconferencing for coordinating activities among them.

The Defence Mapping Agency (DMA) in the United States is sponsoring and coordinating the production of a worldwide video disk library consisting of over 100 disks. DMA has also produced a world disk for global analysis which completely covers the earth's surface at 1:5,000,000 scale with selected coverage at 1:200,000 scale.

Other military users of video disk mapping include the staff colleges, the terrain analysis sections at strategic and tactical levels, and various defence program management offices. The number of users is likely to increase as the Canadian VLD coverage becomes available throughout 1992.

MILITARY APPLICATIONS

The computer software package used by the Canadian Military to display and carry out VLD functions is FULCRUM. Interactive Television Company (ITC) in Virginia developed the FULCRUM system for support to military planning, operational, intelligence, and targeting activities. FULCRUM was used extensively throughout the Gulf War for a wide range of military applications such as mission planning, targeting acquisition for aircraft and missile launchers, situation assessment and threat analysis for intelligence, and briefing support for headquarters.

Not only does FULCRUM use off-the-shelf computer hardware and NATO standardized VLDs, but it also supports the use of various military digital geographic databases distributed on CD-ROM such as World Data Bank II (WDBII), World Vector Shoreline (WVS), Arc Digitized Raster Graphics (ADRG) and soon Digital Chart of the World (DCW) and Digital Terrain Data (DTD). It can also directly access on-line digital gazetteers (list of place names, types, and locations) for automatic map selection and positioning; and Digital Terrain Elevation Data (DTED) for displaying slope profiles, line of sight, terrain masking, slope and elevation overlays, and three dimensional perspective views. FULCRUM capabilities also include a set of tools for map display, measurement, information management, terrain analysis, briefing support, and other basic GIS functions.

The VLD is presently the preferred product for map display background because of its availability, worldwide coverage, good quality images and quick retrieval. It provides the military users with the geographic database needed today to perform a multitude of applications such as:

- Mission planning and control;
- Intelligence collection and analysis;
- Route definition and terrain analysis;
- Event and mission simulation;
- Indexing of collateral information (imagery or text);
- Military information management, query, and display;
- Information exchange among users;
- Training tool for military education;
- Briefing support; and
- Search and Rescue operations.

CONCLUSION

This paper has described the video disk technology as the interim solution for the military to the problem of mass storage of geographic information. It can contain a wide variety of source materials such as paper maps and charts, satellite imagery, aerial photography, and textual documents that can be quickly accessed in a georeferenced format. In the meantime the Defence department will continue to research and develop a vector/raster-based GIS database for the military applications of tomorrow.

When the first series of Canadian video disks at 1:250,000 scale is completed, it is anticipated that DND will have a need for much larger scale products, namely complete VLD coverage at 1:50,000 and select coverage at 1:25,000 scale. It is hoped that this type of initiative will spark more interest among the public and private sectors so that more GIS users can benefit from this relatively cost effective technology.

The Management of Standards in an International Context

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ABSTRACT

We are witnessing a revolution in digital geographic information standards. For the first time there appears to be a growing consensus amongst national, regional and international mapping and charting agencies. The Department of National Defence (DND) has taken a leadership role in this standards effort. Canada, represented by DND, has assumed custodianship of the international Digital Geographic Information Exchange Standard (DIGEST) within the eleven nation Digital Geographic Information Working Group (DGIWG). The DGIWG in November 1991 has taken the unprecedented step to offer DIGEST to the international community by the formation of the DIGEST Steering Committee (SC). The SC is chaired by the Comité Européen des Responsables de la Cartographie Officielle (CERCO) with the objective of establishing DIGEST as an ISO standard by 1994. This paper will explore further these efforts and highlight the leadership role that Canada is playing in this endeavour.

La gestion des normes dans un contexte international

RESUME

Nous sommes présentement témoins d'une révolution dans les normes d'information géographique numérique. Pour la première fois, on voit un consensus se former entre les diverses agences de cartographie nationales, régionales et internationales. Le Ministère de la Défense Nationale (MDN) a pris un rôle de leader dans cet effort de normalisation. Le Canada, representé par le MDN, a assumé la garde des standards pour l'échange d'information géographique numérique (DIGEST) dans le groupe de travail sur l'information géographique numérique (DGIWG) qui est composé de onze nations. En novembre 1991 le DGIWG a pris la mesure sans précédent d'offrir DIGEST à la communauté internationale en formant le comité d'organization de DIGEST. Ce comité est présidé par le Comité Européen des Responsables de la Cartographie Officielle (CERCO) avec l'objectif d'établir DIGEST comme standard international (ISO) pour 1994. Ce papier explore avec plus de détails ces efforts de normalisation et met en évidence le rôle de leader que le Canada joue dans ce domaine.

DEVELOPPEMENT DES S.I.G. POUR LA MISE EN VALEUR AGRICOLE DES TERRES ARIDES ET SEMI-ARIDES: LA PROBLEMATIQUE ET LES ATTENTES

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Résumé

L'agriculture de subsitance traditionnelle, qui marque les terres arides et semi arides, demeure un systeme de production à risques et à faible rendement et ne peut assurer l'autosuffisance alimentaire des populations concernees. la mise en valeur de ces terres doit passer par la modérnisation des systemes de production agricole.
Pour planifier un développement agricole durable de ces terres que cela soit à l'echelle régioale ou locale, il faut disposer de:
(a) Une bonne connaissance des contraintes agricoles spécifiques à la région pour la maitrise des aspects biophysiques et socio-économiques, ainsi que celle de la problématique de l'agriculture
au niveau local, tache multidisciplinaire et de nature foncière appliquée.
(b) L'attribution de zones prioritaires pour l'application des programmes de développement agricole , ce qui nécésaite la cartographie des potentialités agricoles de la région.
(c) Une source d'information précise sur la fiabilité des programmes de développement, les résultats pratiques de la recherche agronomique et les outils de suivi et d'évaluation des programmes d'action.
L'absence d'une telle base de données fiable et opérationnelle et la pénurie de personnel téchnique expérimenté continuent à retarder plusieurs projets de développement agricole dans ces régions. Ce sont là des attentes que les chercheurs et responsables affichent aujourd'hui pour les S.I.G. informatisés. La presente communication illustre la problématique de la mise en valeur agricole des terres semi-arides dans la province de Settat (Maroc) et presente l'organisation du S.I.G (SIGMA)
en cours de dévelopement pour cet effet. Il s'agit d'un projet de recherche appliquée parrainé par le Centre de recherche pour le développement international (Ottawa) et conduit conjointement par des chercheurs marocains et canadiens avec la participation directe de l'organe de développement agricole de la province de Settat

G.I.S. DEVELOPMENT FOR DRYLAND AGRICULTURAL MANAGMENT : PROBLEMS AND EXPECTATIONS

Abstract

The traditionnal subsistance farming that prevails in the arid and semi-arid zones continues to be a risky and less productive system that fails to meet the demand of its growing population. The sustainable agricultural development of these regions can not be possible without the modernisation of the dryland farming systems.
The adequate planning and implementation of the regional dryland development projects require:
(a) A good assessment of the agricultural constraints specific to each region and based on its biophysical and socio-economical aspects. This spatial data analysis is a multidisciplinary task.
(b) Designation of priority zones for the implementation of agricultural development programs.
This requires a precise mapping of the land capabilities in the region.
(c) An accurate information source on the efficiency of the agricultural development programs, the applied results of the agricultural research and the monitoring and the evaluation of projects implementation.
The lack of such a reliable and operational data base as well as qualified technicians is responsable for the delay of many agricultural development projects in these regions. Computerized geographic information systems are emerging as the sptial data handling tools to assist technicians and decision makers to solve the complex dryland farming problems. This paper presents a G.I.S. development project (SIGMA) designed for a semi-arid region of Morocco.

1. INTRODUCTION

De nombreux travaux, ces dernières années, ont porté sur la conception et la mise en oeuvre des systèmes d'information géographique pour le développement rural et la conservation des ressources naturelles dans divers régions du globe. La recherche scientifique n'a pas eu de grandes difficultés à livrer directement, et cette fois ci rapidement, ce concept et outil aux institutions gouvernementales, privées ou communales responsables des différents fonctions de développement rural. Klotz et El Kissi (1991) rappellent que le S.I.G. est né du rapprochement de deux savoir-faire : l'informatique de gestion et la cartographie. Ceci a été facilité par le développement technologique fulgurant qu'a connu la micro-infrmatique et les outils de l'infographie ou cartographie assistée par ordinateur. Ce sont ces deux parents du S.I.G., qui étaient déjà bien introduits au sein des différents organismes de développement rural, qui ont permis cette croissance. Cependant, on observe que cette croissance est inégale quand on compare son utilisation d'aujourd'hui dans le secteur rural d'une part et dans le secteur urbain de l'autre et aussi quand on remarque son succès très modéré dans les pays du sud.
En effet, c'est dans le secteur agricole et dans les pays du sud que l'information de gestion, basée sur une importante base de données spatiales et temporelles fait défaut et limite le succès de toute planification de mise en valeur agricole à l'échelle de la région ou du pays.

L'agriculture dans les pays du Sud et plus particulièrement en zones semi-arides et arides demeure une agriculture de subsistance traditionnelle à faible rendement et à grands risques. Ce secteur ne peut repondre au défi d'assurer l'autosuffisance alimentaire que lui affiche une démographie galopante dans ces régions, sans passer par une modernisation des systèmes de production agricole. Il y a là toutes les justifications pour faire bénéficier ce secteur de cette nouvelle technologie et ce puissant outil de planification et de gestion. Ceci nécessite avant tout un effort particulier de la part des chercheurs pour valider et adapter la technologie des S.I.G. aux besoins de développement agricoles des zones arides et semi-arides.Dans ces régions, les utilisateurs potentiels du S.I.G .attendent encore des démonstrations concrètes répondant à leurs attentes. De ce fait , les firmes et les spécialistes du SIG doivent doubler leurs efforts en matière de vulgarisation et de promotion de cet outil.

La présente communication illustre la problématique du développement agricole dans une région semi-aride du Maroc tout en identifiant les attentes des décideurs et des techniciens . La communication présente les objectifs et les grandes lignes du projet de recherche appliquée intitulé SIGMA et qui vise le développement d'un S.I.G. pour la mise en valeur agricole de la province de Settat (Maroc). Ce projet parrainé par le Centre de Recherche pour le Développement International (Ottawa) implique des chercheurs marocains et canadiens (CRDI, 1991).

2. PROBLEMATIQUE DE LA MISE EN VALEUR AGRICOLE DES ZONES ARIDES ET SEMI-ARIDES : LA MAITRISE DE L'INFORMATION

Les terres arides et semi-arides couvrent environ un tiers des terres émergées du globe. Presque 850 millions de personnes y vivent. L'agriculture de subsistance traditionnelle, qui marque ces terres, demeure un système de production à risques et à faible rendement. Ceci parce que les précipitations y sont plus rares et très variables, les sols sont marginaux et surtout parce que les niveaux d'investissement financiers et technologiques dans les projets de développement sont très insuffisants.

Nous ne prétendons pas, dans le cadre de cette courte contribution, faire un bilan exhaustif des problèmes et des solutions de développement agricole de ces régions. Le lecteur peut trouver plus d'information par exemple dans les actes de la première conférence internationale sur l'agriculture dans les zones arides et semi-arides (Ungir et al., 1988). On s'accorde généralement à reconnaître que la mise en valeur de ces terres doit passer par la modernisation des systèmes de production agricole. Ceci impose un effort considérable de planification rationnelle à différents niveaux. Cette planification doit être basée sur :

(a) Une bonne connaissance des contraintes agricoles spécifiques à la région pour la maîtrise des aspects biophysiques et socio-économques, ainsi que celle de la problématique de l'agriculture au niveau local. Ceci constitue une tâche multidisciplinaire et de nature foncière appliquée.

(b) l'attribution de zones prioritaires pour l'application des programmes de développement agricole, ce qui nécessite la cartographie des potentielités de la région.

(c) Une source d'information précise sur la fiabilité des programmes de développement, les résultats pratiques de la recherche agronomique et les outils de suivi et d'évolution des programmes d'action. L'absence d'une telle base de données fiable et opérationnelle et la pénurie de personnel technique expérimenté continuent à retarder plusieurs projets de mise en valeur agricole de ces zones dans les pays en développement.

Le Maroc où les terres arides et semi-arides couvrent plus des deux tiers du territoire connait ces mêmes contraintes. Fay (1986) a montré au Maroc comment un certain nombre de projets, conçus pour le développement de régions pastorales et forestières, n'ont pas donné les résultats escomptés en raison des erreurs de méthodes commises dans la délimitation des «zones d'action» et d'une structure inadéquate de cellules d'interventions. De toute évidence les problèmes de la mise en valeur des terres arides et semi-arides sont très complexes. Seule l'approche de développement intégré peut garantir des paquets de technologies appropriées et adaptées à l'organisation socio-spatiales de ces zones. Ceci exige l'amélioration et la modernisation de la manière dont techniciens et experts en développement t de la manière dont techniciens et experts en développement agricole appréhendent les espaces ruraux et les populations interessées par les programmes de la mise en valeur de ces terres. Il est alors vital de doter ces techniciens et décideurs d'une base

de données biophysiques et socio-économiques la plus complète et la plus actualisée possible pour leur permettre de réussir la planification rationnelle et la mise en oeuvre des programmes d'acction.

3. LES APPORTS ESCOMPTES DU S.I.G.

La valeur d'un SIG repose principalement sur sa flexibilité à manipuler les données ainsi que sur les produits d'information qu'il peut synthétiser. ERIC DE MAN (1988) suggère que la conception d'un SIG repose surtout sur l'utilité que l'on veut en faire plutôt que sur ses capacités techniques. En agriculture, le S.I.G. doit répondre avant tout au besoin d'associer une information à référence spatiale (géologique, pédologique, topographique, ...) à une information socio-économique dans le but d'optimiser la productivité et la gestion des aménagements agricoles des terres.En effet, les techniciens et experts en développement rural affichent aujoud'hui des attentes en ce qui concerne l'utilisation du SIG qui s'alignent depuis la phase d'identification des projets de mise en valeur agricole des terres jusqu'à leur réalisation et gestion. On peut les regrouper en trois groupes d'exigences:

3.1. Archivage et gestion des données

Les responsables s'attendent à un outil efficace et peu coûteux pour repértorier et évaluer les ressources naturelles, les infrastructures existantes et les activités socio-économiques des populations cibles dans un contexte de planification du developpement agricole. L'utilité du S.I.G. dans ce domaine n'est plus à démontrer.Les zones arides et semi-arides qui sont souvent marginales ou éloignées, ne dispose pas encore d'une base de donnée suffisante pour caractériser leur fonctionnement et leur potentialité. En plus, les données et les informations disponibles sont généralement éparpillées dans différentes institutions. Les documents techniques et surtout les cartes thématiques sont produits en nombre restreint et s'épuisent plus rapidement. Il est alors fréquent de voir des études d'inventaire des ressources en sol , par example, en train d' être refaites car le service régional ne les retrouve plus . Il s'agit donc d'éviter un gaspillage de temps et des fonds qui sont déjà très limités pour ces zones. Le S.I.G. doit permettre alors le stockage efficace et compact sur support archivable et disponible pour une restitution brute, rapide et spatialisée des sont . Il doit aussi permettre une mise à jour facile de l'information existante. Le S.I.G. par ces facilités aidera alors à la décentralisation et à la bonne gestion de l'information agricole à "échelle régionale.

3.2. Analyse et traitement des données

La valeur et les exigences du S.I.G. qu'attendent les agronomes et les décideurs dans ce domaine sont justement ses capacités de manipuler les données ainsi que les produits d'information qu'il synthétise. Les attentes vont de la simple production de statistiques actualisés jusqu'à la modélisation de phénomènes complexes impliquant la productivité des terres ou le fonctionnement des exploitations dans différentes situations biophysiques et

socio-économiques. Seule l'approche du développement intègré peut sauver l'agriculture des zones arides et semi-arides.Ceci impose une approche systématique et un outil rapide d'intégration et de gestion de l'information rurale et agricole pour (i) mieux planifier la mise en valeur des terres au niveau provincial ou de la commune rurale (ii) servir de base à la prévision des récoltes et (iii) orienter les investissements et la recherche agronomique là où les besoins et les bénéfices économiques apparaissent les plus grands.
De tous les techniciens du développement agricole, les pédologues sont les premiers bénéficiaires du S.I.G.. Ce dernier doit leur permettre l'analyse informatisée rapide et précise des données et des cartes pédologiques pour déterminer la vocation agricole et les aménagements appropriées au niveau local et régional (Merzouk et al.,1990). L'analyse de telle information thématique dérivée se prête aussi à toute modification ou ajustement à tout moment à la suite de compléments d'information.Au Maroc on a fait récemment appel au S.I.G. pour l'analyse des facteurs et la modélisation de l'érosion hydrique dans les bassins versants. Ce S.I.G.est appelé aussi à formuler les schémas d'aménagement des bassins versants et suivre leur mise en oeuvre (F.A.O., 1987).

En fait, les attentes sont plus ambitieuses car il n'y a pas un seul décideur ou technicien impliqué dans la mise en valeur des terres arides et semi-arides qui ne souhaite pas voir le S.I.G., par ses capacités d'analyse, évoluer en un système expert pour l'aider à la prise de décision

3.3. Edition sous forme directement utilisable des données de base et des documents thématiques dérivés.

Au Maroc, comme dans d'autres pays en développement, la réalisation des études de mise en valeur agricole et l'édition de leur documents cartographiques restent du ressort des bureaux d'études étatiques ou privés. C'est un processus qui est lent et onéreux et qui surcharge les services de cartographie «traditionnels» qui sont généralement très centralisés. Cette situation prive les services régionaux de la mise en valeur de la possibilité de modifier ou d'ajuster la base de donnée à tout moment à la suite de compléments d'information ou d'événements exceptionnels (sécheresse prolongée, inondation; ...) et d'imprimer les résultats. Il s'agit bien entendu des documents cartographiques, car tous les facteurs de production y compris le facteur humain sont très spatialisés. La cartographie est un des atouts les plus forts du S.I.G. et qui lui permet de répondre aux attentes de ces utilisateurs. L'édition au coup par coup, simple et immédiate, des documents produits (rapports, cartes, schémas d'intervention, ...etc.) est rendue possible aujourd'hui avec les compétences du S.I.G. L'utilisateur doit y trouver une grande flexibilité dans le mode de représentation des documents thématiques (échelle, extraction des zones cibles pour intervention, ...) et une rapidité d'édition. L'informatisation de la cartographie par le S.I.G. doit offrir, en plus ,d'autres avantages qu'on ne peut énumérer ici, tels que le calcul automatique des surfaces.

4. PROJET SIGMA: DEVELOPPEMENT D'UN S.I.G. AGRICOLE

Il s'agit d'un projet de recherche appliquée, qu'à entrepris, depuis Mai 1991, le Département des Sciences du Sol (DSS) de l'Institut Agronomique et vétérinaire Hassan II (I.A.V. Hassan II) avec la participation de la Direction Provinciale de l'Agriculture (DPA) de Settat et avec la collaboration des chercheurs du Centre d'Applications et de Recherches en Télédétection (CARTEL) de l'Université de Sherbrooke, Quebec, Canada. Ce projet vise à l'élaboration d'un système d'information géographique pour la mise en valeur agricole (SIGMA) et son application à une région d'agriculture pluviale du Maroc: la région de Settat.

Au Maroc , l'agriculture est la base de l'économie nationale. Une grande proportion de la population rurale y est employée (55% de la population totale du pays en 1987). Ce secteur dispose d'environ 8 millions d'hectares de terres dont la majorité se situe dans les zones semi-arides. Il est reconnu que l'autosuffisance alimentaire du pays ne peut se réaliser qu'avec l'amélioration et la stabilisation de la production dans ces régions, leurs rendements potentiels étant largement supérieurs aux rendements actuels.

La politique agricole du pays, orientée vers l'amélioration des conditions de vie des agriculteurs et l'autosuffisance alimentaire, s'appui, depuis le début des années 70, sur une décentralisation des services du Ministère de l'Agriculture et de la Réforme Agraire . Les Directions provinciales de l'agriculture ont été ainsi crées pour promouvoir le développement agricole à l'échelle régionale. Les DPA sont chargées, dans le cadre des directives de l'administration centrale, d'appliquer la politique agricole arrêtée par le gouvernement , notamment, dans les domaines de :

- l'équipement rural et l'aménagement des structures foncières;
- l'organisation de la production agricole, végétale, animale et forestière.
- la réforme agraire
- les études économiques et les enquêtes statistiques; et
- la vulgarisation agricole et l'organisation professionnelle des agriculteurs.

Face à cette multitude de tâches, d'actions et de décisions qu'exige le développement agricole de chaque région, et aussi à la complexité des systèmes d'exploitation traditionnels, une approche par projets de développement intégré a été adoptée par plusieurs DPA. La DPA de Settat, considérée comme la DPA pilote dans la zone d'agriculture pluviale, couvre une superficie d'environ 1 million d'hectares. Dès 1980, cette DPA a engagé les études pour son projet de développement intégré. Ce projet touche principalement:

- La production céréalière avec des actions d'intensification des productions agricoles et animales;
- et - l ' amélioration foncière et le développement des infrastructures sociales et économiques.

4.1. Objectifs du projet SIGMA

L'objectif général de SIGMA consiste en la mise au point d'un système d'information agricole à référence spatiale qui permettra de répertorier, collecter et évaluer les ressources d'une région d'agriculture pluviale dans un contexte de planification et de mise en valeur agricole. Comme précisé plus haut, ce système sera développé conjointement avec les gestionnaires et les techniciens de la D.P.A. de Settat (Maroc) et par conséquent, appliqué immédiatement à la solution de problèmes réels de la région.

Les objectifs spécifiques et les résultats anticipés sont :

a) La collecte de l'information et l'établissement d'une base de données informatisée et géocodée de la région de Settat qui comportera de l'information à caractère physique et thématique (relief, géologie, hydrologie, pédologie, potentialités culturales et élevage, etc.) et socio-économique y compris les infrastructures anthropiques (routes, villes, villages). Les données de télédétection satellitaire (images LANDSAT et/ou SPOT) serviront comme une source auxilliaire de données pour la mise à jour de l'information sur la couverture et l'utilisation du sol.
b) La réalisation de documents cartographiques thématiques relatifs aux pentes, à l'utilisation du sol, à la pierrosité des terres, et aux caractéristiques agroclimatiques (précipitation, déficit hydrique, etc.) pour une période de temps donnée.
c) La production, à partir de la base de données, d'un premier inventaire sur les potentiels des terres en fonction du type de culture, du niveau de production, du type d'exploitation et du volume des intrants. Des cartes des potentialités des terres, des zones d'intervention pour l'épierrage du sol, du déficit hydrique et du rendement agricole seront ainsi produites.
d) Le développement d'une méthodologie d'intégration des données de télédétection à SIGMA, pour la mise à jour de l'information sur la ,couverture du sol et la dynamique de son occupation en fonction des différentes opératons de mise en valeur (irrigation, opération d'épierrage, travaux de conservation des sols et des eaux).
e) Au travers ce projet pilote, démontrer aux responsables de la DPA l'efficacité de la technologie des SIG et du traitement numérique des images satellitares pour la gestion de l'information rurale et agricole. Il s'agira donc de leur donner les moyens de constituer, utiliser et mettre à jour une base de données, et d'entreprendre les analyses d'identification des dfférentes stratégies de mise en valeur agricole des terres en vue de leur emploi optimal.
f) La formation des enseignants-chercheurs du DSS et des techniciens de la DPA de Settat à l'utilisation du SIG et de ses différentes composantes et au développement d'applications.
g) Parallèlement à ces objectifs, développer les liens et multiplier les rapports entre les enseignants-chercheurs de l'IAV Hassan II et les professionnels, planificateurs et décideurs du développement régional. Ceci donnera à la recherche et à la formation de l'IAV Hassan II une orientation pratique basée sur la réalité marocaine.
h) La diffusion des résultats du projet de recherche aux autres DPA des régions d'agriculture pluviale du Maroc, en particulier, et des pays du Sahel et d'Afrique du Nord, en général.

4.2. Méthodologie

SIGMA utilisera des données physiques à références spatiales et des données socio-économiques. Une grande partie de ces données est déjà disponible au niveau de la D.P.A. Les données manquantes seront collectées dans le cadre du projet. L'utilisation d'images satellite (SPOT et LANDSAT TM) pour l'inventaire des ressources et de la couverture du sol permettra de renforcer le processus de collecte de données par les méthodes traditionnelles (photographies aériennes, relevés sur le terrain) et la mise à jour rapide de ces données.
La figure 1: schématise les différentes phases de l'élaboration et du fonctionnement de SIGMA.

5. CONCLUSION

Face à une démographie galopante et des conditions climatiques de plus en plus sevères, l'agriculture des zones arides et semi-arides ne peut garantir l'autosuffisance alimentaire des populations qui y vivent sans une modernisation rapide de ses systèmes de production. L'analyse des problèmes et le défi que pose cette agriculture fragile à poussé les experts lors de la conférence internationale d'Amarillo (Unger et al, 1988) à annoncer le début de la deuxième révolution verte et qui concerne les zones arides et semi-arides. La modernisation exige avant tout la planification judicieuse et la mise en oeuvre, pour ces zones, des programmes de développement agricole à l'échelle régionale. Ceci demande une approche systémique et un outil d'intégration et de gestion quotidienne d'une base de données fiable et à jour. C'est bien là, où cette deuxième révolution verte doit s'accrocher à la grande révolution technologique qu'à connu ces dernières années la micro-informatique de gestion et la cartographie assistée par ordinateur. Le S.I.G., dernier fruit de cette révolution, répond bien aux attentes des techniciens et experts en développement agricole. Il leur permet une meilleure maitrise, gestion et décentralisation de l'information agricole. Par ses capacités d'analyse, le S.I.G. procure une flexibilité considérable et un gain de temps qui permettent aux décideurs l'élaboration rapide de différentes stratégies de mise en valeur des terres en vue de leur emploi optimal.Le développement du S.I.G. agricole doit répondre aux problèmes et attentes spécifiques à chaque région. De ce fait, la recherche appliquée impliquant les spécialistes du S.I.G., les décideurs et techniciens du développement agricole et les firmes qui développent cette technologie doit préceder tout effort de sa vulgarisation et sa promotion dans les régions arides et semi-arides, où s'il faut le rappeller encore, les fonds sont déjà bien limités. Le projet SIGMA constitue un exemple de cette démarche dans la promotion de l'utilisation du SIG pour la mise en valeur agricole des terres arides et semi-arides au Maroc.

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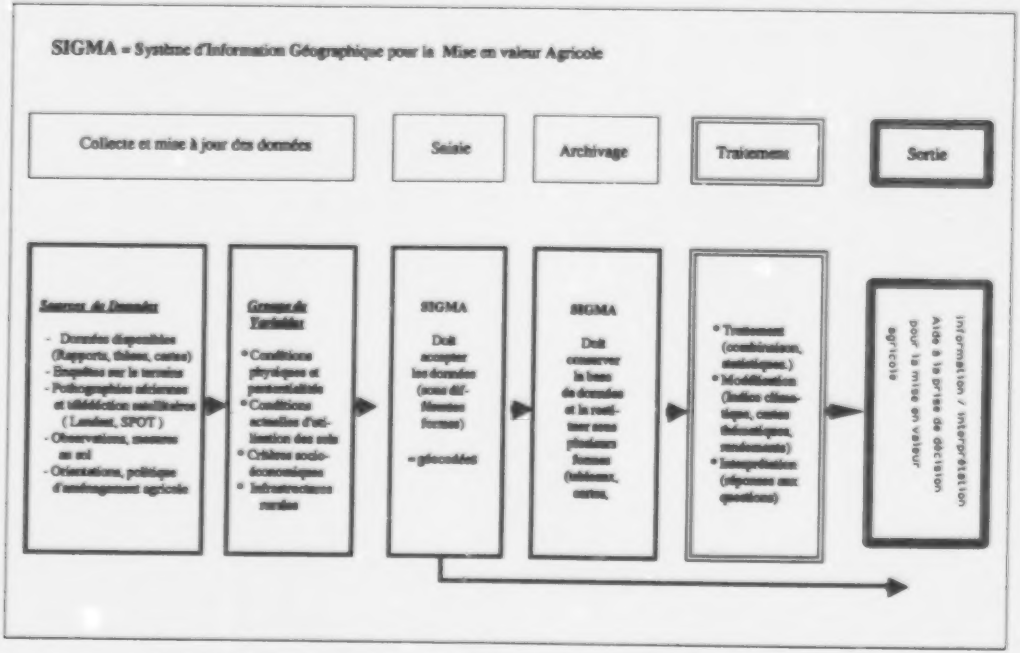

Figure 1 : Les différentes séquences du montage et du fonctionnement du SIGMA

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CONVERTING THE LAND RESOURCE MAPPING (LRMP) DATA INTO A GIS MODEL TO EVALUATE THE FOOD, FEED AND FUELWOOD RESOURCES OF NEPAL

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ABSTRACT:

In the early 1980's a 1:50000 scale integrated Land Resource Mapping Program (LRMP) was completed for all of Nepal. This included an inventory of the soils, landform, geology, agriculture, forestry and selective socio-economic resources. This information was converted into a digital database and linked to a GIS via a spreadsheet model. For each of the 75 districts, production and consumption were calculated for 1) food (based on eight basic crops), 2) feed (based on all major agricultural and forestry resources), and 3) fuelwood (based on all types of available forests, shrub and grazing lands).

As part of the evaluation, color coded GIS displays were produced to indicate which districts have deficit or surplus conditions for the various resources. Using the current population growth data, scenarios were made to show in what year each district reached the point of non-sustainability. Finally, a sensitivity test was made to determine which variables are most sensitive in altering the resource output.

The evaluation showed surprising results. The feed resources are most critical in the Middle Mountains and Lowland districts. The food resources are most critical only in selective districts in the Terai and the Middle Mountains and the fuelwood status is generally the least critical of the three resources.
The model with its GIS link is dynamic and flexible and allows us to examine different development scenarios at will. We perceive the model to be an excellent tool to assist international aid programs and to be used as a decision support system for resource managers, land use planners and decision makers.

CONVERTIR LES DONNÉES DE CARTOGRAPHIE DES TERRES EN UN MODÈLE SIG POUR ÉVALUER LES RESSOURCES DU NÉPAL (BOIS DE CHAUFFAGE, ALIMENTS POUR LE BÉTAIL ET L'HOMME)

RÉSUMÉ

Au début des années 80, un programme intégré de cartographie des terres a été réalisé à l'échelle de 1/50 000 pour tout le Népal. Cela comprenait un inventaire des sols, des formes superficielles, de la géologie, de l'agriculture, de la foresterie et de certaines ressources socio-économiques. Cette information a été incluse dans une base de données numériques et reliée à un SIG au moyen d'un tableur. Pour chacun des 75 districts, on a calculé la production et la consommation : 1) des aliments pour les humains (fondés sur huit cultures de base), 2) des aliments pour le bétail (fondés sur toutes les principales ressources agricoles et forestières) et 3) du bois de chauffage (fondé sur tous les types de forêt, d'arbustaies et de pâturages disponibles).

L'évaluation a comporté la production d'affichages de SIG chromocodés permettant d'indiquer les districts présentant des conditions de déficit ou de surplus pour les diverses ressources. À l'aide des données actuelles sur la croissance de la population, des scénarios ont été élaborés pour déterminer l'année à laquelle chacun des districts a atteint le point de non viabilité. Finalement, un test de sensibilité a été appliqué pour déterminer les variables les plus sensibles à la modification de la production des ressources.

L'évaluation a produit des résultats surprenants. Ainsi, les ressources en aliments pour le bétail étaient les plus menacées dans les districts du Moyen Himalaya et de la zone de plaine. Les ressources en aliments pour l'homme sont les plus maigres dans quelques districts du Terai et du Moyen Himalaya; le bois de chauffage est généralement la ressource la moins menacée des trois.

Grâce à son lien SIG, le modèle est dynamique et flexible et nous permet d'examiner divers scénarios de développement. Le modèle nous semble un excellent outil pour les programmes d'aide internationale et pour les systèmes d'appui des décisions qu'utiliseront avec bonheur les gestionnaires des ressources, les aménagistes et les décideurs.

GAINING FORESTS BUT LOSING GROUND; A GIS BASED RESOURCE EVALUATION OF THE JHIKHU KHOLA WATERSHED IN NEPAL

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ABSTRACT:

The Jhikhu Khola watershed was chosen in 1988 as a test area to monitor land use dynamics and to quantify resource degradation processes in the most intensively used area in the Middle Mountains of Nepal. A 1:20000 scale digital database was developed for all basic resources and major processes such as soil erosion, nutrient cycling, degradation and conversion of agricultural and forestry land were quantified. A Geographic Information System (GIS) was used to evaluate the resource dynamics and to determine which of the land use practices are sustainable under current input and use intensity.

It has long been claimed by such organisations as the World Bank, the Asian Development Bank and the media, that deforestation has reached catastrophic levels in the Himalayas and as a result of the recent devastating floods in Bangladesh the Nepali farmers have been accused of being at least partially responsible for the problem. Based on a careful examination of the historic data and a GIS based evaluation of past and current land use it is evident that significant deforestation has occurred during the 1960's and 1970's, but there is clear evidence that the forest cover has increased over the past ten years as a result of community based afforestation programs. What makes these findings more important is the fact that the population density and land use intensity in the test area is amongst the highest in any mountainous terrain in the world. This indicates that without quantitative GIS based evaluations perceptions can be very misleading and can influence development priorities in a very negative way.

The most important findings of this study are that while the forest cover is increasing, the soil fertility status of both agricultural and forestry land are declining rapidly as a result of increased use and limited input. This is putting into question the long term sustainability of both resources. The presentation will focus on how GIS techniques can be used to assist in integrated resource evaluations. It will document the resource dynamics in the Middle Mountains between 1947 and 1990, it will identify the key degradation processes and will provide scenarios for achieving sustainable resource use over the next ten years.

ON GAGNE DES FORÊTS MAIS ON PERD DU TERRAIN; UNE ÉVALUATION DES RESSOURCES DU BASSIN HYDROGRAPHIQUE DE LA JHIKHU KHOLA, NÉPAL AU MOYEN D'UN SIG

RÉSUMÉ

En 1988, on a choisi comme zone d'étude le bassin hydrographique de la Jhikhu Khola, afin de surveiller la dynamique de l'utilisation des terres et quantifier les processus de dégradation des ressources dans la région la plus intensivement utilisée du Moyen Himalaya du Népal. Une base de données numériques à l'échelle de 1/20 000 a été créée et les principaux processus de l'érosion des sols, les cycles d'aliments nutritifs, la dégradation et la conservation des terres agricoles et forestières ont été quantifiés. Un système d'information géographique (SIG) a été utilisé pour évaluer la dynamique des ressources et déterminer lesquelles des pratiques d'utilisation des terres assurent la viabilité compte tenu des facteurs de production et de l'intensité d'utilisation actuels.

Les médias et certains organismes comme la Banque mondiale et la Banque asiatique de développement déclarent depuis longtemps que la déforestation a atteint des niveaux catastrophiques dans l'Himalaya et, par suite des inondations dévastatrices qu'a récemment connues le Bangladesh, que les fermiers népalais étaient au moins partiellement responsables du problème. D'après un examen attentif des données historiques et une évaluation, fondée sur SIG, des utilisations actuelles et passées des terres, il apparaît clairement qu'une déforestation marquée s'est produite au cours des années 60 et 70; certains faits montrent bien cependant que le couvert forestier s'est accru au cours des dix dernières années, grâce à des programmes communautaires de reboisement d'extension. Ce qui rend ces résultats plus importants, c'est le fait que l'intensité de l'utilisation des terres et la densité de la population dans la zone d'étude sont parmi les plus élevées de tout terrain montagneux du monde. Cela indique que s'il n'y avait pas d'évaluation quantitative fondée sur SIG, les perceptions pourraient être très trompeuses et même influencer les priorités de développement dans la mauvaise direction.

Le résultat le plus important de la présente étude : pendant que le couvert forestier augmente, la fertilité du sol des terres tant agricoles que forestières décline rapidement à cause d'un accroissement de l'utilisation et d'une limitation des facteurs de production. Cela remet en question la viabilité à long terme de ces deux ressources. La présentation sera axée sur la façon dont les techniques de SIG peuvent être utilisées pour aider aux évaluations intégrées des ressources. L'article documentera la dynamique des ressources dans le Moyen Himalaya entre 1947 et 1990, déterminera les processus de dégradation clés et fournira des scénarios qui permettraient une utilisation viable des ressources au cours des dix prochaines années.

GIS FOR DEVELOPMENT PLANNING IN INDIA

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ABSTRACT

Indian planning is highly centralized in nature and more fiscal than physical in its terms of reference. In a system where data is fragmentary and inadequate, there is little information on physical assets and infrastructure, vital for development.

The state of Bihar in eastern India is vast in terms of area and population. There is very limited data available for sub-units of the state. The Bihar Cartographic Database was established with a view to solving this problem. Data was collected from diverse sources such as topographic maps, government departments and the census. The main sectors for which data are recorded include demography, education, communication, health, banking, and so on.

Using this database, it has been shown that better, informed planning decisions can be made using GIS procedures than is possible manually or within a non-spatially referenced system. To enable planners in India to make active use of this tool, the government must reconsider its approach to control and distribution of maps and access to government departmental data. Developing GIS skills would be essential. Other measures necessary are strengthening of routine data collection and establishing decentralized repositories of data by both government and non-government agencies.

SIG ET PLANIFICATION DU DÉVELOPPEMENT EN INDE

RÉSUMÉ

En Inde, la démarche de planification est extrêmement centralisée de nature et plus financière que physique dans son organisation. Dans un système où les données sont fragmentaires et insuffisantes, il y a peu d'information sur les caractéristiques physiques et l'infrastructure, nécessaire au développement.

Le Bihar, état de l'est de l'Inde, est vaste en termes de superficie et de population. Les données y sont très limitées. La base de données cartographiques de Bihar a été mise sur pied en vue de résoudre ce problème. On a amassé des données auprès de diverses sources comme les cartes topographiques, les ministères du gouvernement et le recensement. Les principaux secteurs dans lesquels on a amassé des données comprennent la démographie, l'éducation, les communications, la santé, l'activité bancaire, etc.

On a montré, à l'aide de cette base de données, que des décisions de planification, mieux informées, pouvaient être prises grâce aux techniques de SIG qu'il n'était possible de le faire à la main ou avec un système sans référence spatiale. Afin de permettre aux planificateurs indiens d'utiliser au mieux cet outil, le gouvernement doit revoir son approche de contrôle et de distribution des cartes et d'accès aux données ministérielles. Le développement de compétences en matière de SIG serait essentiel. D'autres mesures nécessaires : le renforcement de la collecte régulière de données et l'établissement d'archives de données décentralisées par les organismes tant gouvernementaux que non gouvernementaux.

BACKGROUND

Bihar is an eastern state within the union of India. It is large in terms of area (173,877 sq.kms. of surface area), number of settlements (220 towns and 67,546 inhabited villages) and size of population (86 million in 1991). All the problems that are associated with large, densely populated and extremely poor areas of the developing world manifest themselves in Bihar. The state is characterized by endemic socio-political violence and economic backwardness. Bihar is also not without its share of natural disaster. Large areas of the state are inundated by floods in the monsoon and following months.

In recent years there has been increasing concern at the slow rate of progress in Bihar. The National Planning Commission, the apex planning agency of the government of India and the Centre for Policy Research, New Delhi, were interested in studying different aspects of development, or the lack of it, in the state. There was a need to study the disparities in the levels of development in the different parts of the state and suggest areas where development effort was to be aimed. But such a structured study was fraught with problems relating to data. Besides relevant data often being inaccessible, much did not exist. For instance, nowhere could one get a reliable list of institutions for higher education in Bihar, nor was there any information on dropouts from schools. It was clear that there were many serious lacunae of data in the state and it would be useful to organize what was available from a multitude of sources, recorded at different units of area. This required the creation of a database for the sub-units of Bihar.

One feature of developmental planning in India is that much of the monitoring and evaluation of development programs is on the basis of financial figures relating to allocation of funds and their expenditure. But there is much less concern for the physical assets that are created. The database to be developed for Bihar would need to reflect the physical infrastructure that is available in the state, since infrastructure is closely associated with development in any area. However, a database without a spatial component would be of limited value and so the development of a GIS was mooted. My own interest in the application of GIS for public administration and planning decision support led to the development of the Bihar Geographic Information System Project. The International Development Research Centre, Canada, provided financial support.

The Bihar Geographic Information System Project was established at Kirori Mal College, University of Delhi, in mid 1989. The Project became operational in stages from early 1990 and its objectives were successfully fulfilled by the end of 1991.

OBJECTIVES

The Bihar GIS is one of the few in India which is not directly undertaken or funded by the Government of India or a state government. GIS has been used in India recently by government agencies for the mapping of wastelands and locating subsoil water, mainly using remotely sensed data. This Project differs in

that it uses more socio-economic and demographic than physical data. Its sources of data are predominantly map, census and government departmental data. The aims and objectives of this project are concerned with the testing of GIS tools and methods for making spatial decisions in a developing country and the creation of a database for the study area. The more specific objectives of the Project are listed below:

1 To gather demographic, social and infrastructural data available on Bihar and to keep them under one umbrella. This would enable administrators, planners, researchers and other groups with an interest in the state to easily and quickly access the data. This involved making an inventory of data from various sources and creating the Bihar Cartographic Database (CDB).

2 To present this data in such a manner that it can provide meaningful insights into the present position of infrastructure and can point to areas where greater development effort should be made. To enable this, it was decided to use GIS procedures to present output of analyzed data in graphic and mapped form wherever possible.

3 To create the Bihar CDB in such a manner that it will be possible to update and expand it later with a view to making it a permanent source of information on the region. Thus a reference system in the form of a data dictionary is to be maintained to keep a record of all data that is added to the database.

4 To keep a record of the operational problems that are encountered during execution of the project. Information regarding operational costs, time schedules, equipment, software, sources of data, quality and resolution of data is to be maintained.

5 To disseminate knowledge of Computer Aided Cartography and GIS by conducting workshops and seminars for students, planners, researchers and administrators.

6 On the basis of the experiences and findings of the Bihar GIS Project, to make recommendations regarding policy related to data and information systems in India.

THE BIHAR CARTOGRAPHIC DATABASE

A very substantial part of the Project was the creation of the Bihar CDB from a large number of sources; published and unpublished, fragmentary and complete, contemporary and dated, some questionable but others of fairly reliable quality. The Bihar CDB is today the most comprehensive repository of digital data on Bihar and is available for access by various users. The locational data is grouped into four broad areas of focus. These are administrative units, settlements, communication and physiography.

For the Bihar CDB, location data was input only from paper maps. Twenty eight adjoining map sheets of map scale 1:250,000 were used to create the Bihar CDB. At present the database does not have any data from remotely sensed sources. It was built using the PC ARC/INFO STARTER KIT and PC ARCEDIT modules of PC ARC/INFO. This software package uses a topological structure and requires all features to be stored as either points, lines or polygons. The basic unit in which all features are stored are,

therefore, points (eg. villages or spot heights) or lines (eg roads and streams) and polygons (blocks, districts and towns). The attribute tables are stored in PARADOX 3.0, a relational database management software (RDBMS), and the data is exported to PC ARC/INFO. Attribute data includes details of aerodromes, post offices, hospitals, schools, bank branches, telephone exchanges and more.

The research team consisted of two full time research assistants and the project leader (that is, myself).

EXAMPLES OF GIS APPLICATIONS IN PLANNING

One of the obvious fields of GIS application for planning is in the area of site selection and location of facilities. Another is to demarcate special purpose areas according to a set of criteria defined by the government. In Indian planning, many sectoral funds are allocated by the central and state governments to these areas to support special development programs. However a number of these criteria are difficult to apply in view of both the large size of the country and the complexity of definitions. This is thus one of the obvious areas where GIS can play a very important role in decision support in planning. Three examples from the Bihar GIS project are included here to show how planning decisions in Bihar were made simple by using GIS tool.

Selection of districts for locating new schools: While there are many problems affecting education in Bihar, one of the acutest must be the deprivation of the girl child from educational facilities at all levels. Figures relating to number of school students in the different districts of Bihar, clearly brings out the discrepancy in numbers between girl and boy students. This is a pattern that is consistent at all the four levels: primary, middle, secondary and senior secondary. When the problem is so widespread, which are the districts to be tackled first? Map 1 shows all districts where there are more than ten times the number of schools for boys than there are for girls. These maps show the districts where girls' schools must be established urgently. The reasoning for this is that the number of girls and boys within any age-group are more or less the same, but the girls' have far fewer schools to go to.

Demarcation of special purpose areas: Bihar has a substantial tribal population. The tribal people are concentrated in the hilly and forested areas of the plateau. They have an economy and socio-cultural systems that are quite distinct from the rest of the population of Bihar. Most of the areas that the tribals live in are poorly served by any form of infrastructure for development.

To bring the tribals into the mainstream of development, the Government of India outlined the tribal sub-plan for areas with a majority of tribal population. All blocks with a tribal population of over 50% of the total population qualified for special grants under the Integrated Tribal Development Projects. Later, pockets of tribal population, where tribals formed clusters of at least 10,000 (later changed to 5,000) were also

included.

There are 587 blocks in Bihar. The total population and tribal population figures were used to select the tribal blocks and tribal pockets. There were seventy-four blocks which had more than fifty percent tribal population in 1981. The block level population data from the 1991 census is not yet available.

The areal or administrative units to form the 'pocket' was not specifically defined as either village or block. But it can be assumed that the community development block was kept in mind since this was the unit for which allocations of funds were to be made. Of the 513 blocks that have a tribal population of less than half the total population, 85 have more than 10,000 tribals in the block while another 33 blocks have a tribal population of between 5000 and 10,000. Thus, in all 192 blocks in the state were found eligible for funds under the Integrated Tribal Development Projects.

Selecting towns with poor regional connections: The construction of good communication and transportation facilities is recognized as one of the essential features for the economic development of any area. Thus it is important that all towns be connected to the regional communication network by ensuring that they have access to the main roads and railway lines. This can be done by first identifying all towns that do not have access to roads and railway and then taking corrective measures by providing these connections.

In the present exercise access to the regional surface communication network has been defined as location of a highway or railway station within five kilometers of a town. If the distance between a town and a highway is less than this, then the town is said to have access to the road. Similarly, if a town has less than five kilometers distance between it and a railway station, then it has access to the railway system.

The method used for this exercise was to first select all the towns in the state of Bihar from the study area. There are two hundred forty-six towns in the study area of which two hundred and twenty are in Bihar. Then all the highways were selected from a digitized map of metalled roads. The next step involved generating a five kilometer buffer along the selected highways and around all railway stations. Finally the towns coverage was overlaid with the digital map of buffers. This made possible grouping of all the towns that fall within the buffer and those that are outside it (see Map 2). The twenty-two towns that are remote and have tenuous links to the road and railway network were then identified.

OPERATIONAL PROBLEMS

As the experience of the Bihar GIS shows, a number of operational problems have to be contended with when running a GIS in India. Awareness of these is essential before one is to embark on planning a GIS elsewhere in India. The intention is not to dwell to greatly on the many problems but to highlight the common ones which are likely to be encountered by others in the different states of the country. In my view, the greatest problems relate

to availability of data, access to maps, precarious power situation, unreliable service support and lack of technical skills.

Electricity: One of the major problems of working with computers outside of the largest cities in India is the precarious electricity situation. This may seem strange to those not familiar with conditions in developing countries, but is accepted as part of working here. There are two kinds of problems one faces. One, when there are many hours of power cuts, often not scheduled, so that the Uninterrupted Power Supply (UPS) also stops functioning and batteries cannot be sufficiently charged. Another kind of problem is the fluctuating voltage which can easily ruin the computer and adapters for plotters, to mention only a few. Thus one must invest in spikebusters, UPS and voltage stabilizers to ensure the health of the equipment.

Service support: In Bihar, in spite of its large size and the numerous cities in the state, at the time of this project, there was no agency that could provide immediate servicing facilities. Service personnel were located in the adjoining states and the nearest service centers were about four hundred kilometers away. Vendors of equipment usually send their engineers to cities like Patna (the state capital of Bihar) when they have to attend to a few sites and this causes great loss of time. Even in Delhi, the actual time taken to repair equipment can sometimes take months if components have to be replaced. This is because computer components have to be imported and few vendors have ready stock.

Skilled personnel: Computer literacy is still at a very low level in India outside the major metropolitan cities. It is, therefore, no surprise that skills in Computer Aided Cartography and GIS are negligible. Fortunately, there are a large number of individuals who are trained in manual Cartography and they form the obvious group to choose from for training in GIS. There is also a high degree of mobility among the trained persons as there is a great shortage of such people in the market.

Data: The problem of fragmentary, unreliable and inaccessible data is fairly common in developing nations. But the problem appears to be acute in the case of Bihar, and probably many other states of India. Unless the problem of data is solved, there can be no clear understanding of development problems. Consequently, the generation and organization of data becomes the first step in development planning.

Data exists for each state government department for its own use, and so, there are a large number of sources of sectoral data aggregated at the district level. This data can be collected from the state head quarters. However, sectoral data are often not available at the district head quarters for any sub-units of the district, such as the block or village. The implication in today's context is that although there is stress on devolution of the planning process and district level planning, there is little realization among the policy makers that effective district level

planning can only take place if there is a repository of district level data.

One of the most disturbing aspects of work relating to secondary data in India is that even when data is published, the distributing authority tends to imply that it has the right to withhold it. Quite often letters of authority are asked for data which should normally be open to all. This shadow of secrecy surrounding government data and the problems encountered in getting them is one reason for data being under-utilized by researchers. It also explains why the departments are often not concerned about improving data quality.

Access to maps: In this country, the Survey Of India (SOI) under the Department of Science and Technology is the chief map-making organization. Maps are supplied to the public through a number of SOI map sale offices. Any frequent user of SOI maps will know of the numerous problems regarding the acquisition of maps of scales 1:250,000 and larger. The problems range from inadequate stocks ('presently not available') to 'restricted'. For acquiring restricted maps, a clearance from the Ministry of Defence is required. Even when given, it can take up to a year from applying for a map to receiving the clearance. This naturally causes a tremendous loss of time. But the long term ramification of this unspoken discouragement of the public use of maps has been that researchers and academics have studiously neglected studying the 'restricted' areas. These include topographic maps of areas that fall within a fifty kilometer belt of the international land and coastal boundaries of the country and those maps that are gridded.

Old maps: A substantial part of the Bihar Cartographic Database was created in the years 1989-1990. The map data were much older. There is a tremendous time lag between the survey of an area and the production of the paper map. The most recent SOI 25,000 scale maps of Bihar published in 1986 were surveyed in 1974. The implies that while the maps were being digitized in 1990, they were, in fact, reflecting ground conditions of a decade and a half earlier. Clearly the map data, for some elements at last, was already questionable.

Temporal changes taking place on the ground cannot possibly be shown on a static map. However, a number of map frames depicting the same area at different time phases, could be an answer to overcoming this problem. Unfortunately, for most areas only one map was printed in the last three decades. With automation in map production, it is hoped the problem of spatial data being outdated, even as the map becomes available for public use, will be overcome.

One aspect of change that maps can hardly keep pace with is the changes relating to boundaries of administrative units, especially the revenue district. In 1981 there were thirty-one districts in Bihar, in 1990 there were thirty-nine, in 1991 forty-two and today there are fifty-one. Since much of the government departmental data is aggregated at the district level, and these are often not available for a smaller unit, this was a

major problem to contend with.

Maps and other records: Errors can creep in in many different ways as was noticed when digitizing for Bihar. Quite often there is more than one settlement of the same name both in the map and in the departmental file. However, there is no way to judge which record in the table applies to which settlement on the map. Sometimes, names change and the change is not reflected in the maps. Occasionally, settlements that appear fairly important on the map do not appear in the Census records. At other times, though very rarely, villages on the extreme edges of some SOI map sheets are repeated on the edge of adjoining map sheets, leading to duplication. It is also unlikely that large scale topographic maps and the District Census Handbook maps correspond entirely.

POLICY CONSIDERATIONS AND ISSUES

GIS in India is only beginning. Much needs to be done to promote GIS as a tool for planning. The enormous potential of this tool for spatial planning has hardly been tapped. Before the fullest use of this technology in management and decision support can be made, a number of steps should be taken. These include matters relating to control and distribution of maps by the government and strengthening of routine data collection. An important consideration for the future would be to create facilities for training and providing support in promoting GIS.

Education: In India, it is very often the case that users are not aware of the potential of their data. Most people are familiar with databases that hold descriptive texts and numeric data in tables. But the use of even paper maps is very limited. be Potential users of GIS should be exposed to the possibilities of map data and the power of GIS for integrating and combining such data. This can easily be done by holding short demonstrations, as was done many times during the Bihar GIS project. Real life situations from India and other developing countries, where GISs have been used to make better decisions than would otherwise be possible, can be shown.

Intensive short and long term courses need to be designed for GIS administrators and operators. The stress would be on the use of micro-computers that could be serviced locally in all states. It is not necessary to use the most sophisticated GIS software packages. Inexpensive GIS with perhaps only limited functions can be used. Once GIS skills become widespread, and the general atmosphere is more conducive to the use of computers, the use of better equipment and more sophisticated software could be encouraged.

Use of maps: It would not be an exaggeration to say that a remarkably small number of the literate Indians have ever used a map for any purpose at all. The lobby for access to maps has not generated as much public interest as the freedom of the press or radio or television. This is precisely why the mapping agencies have been able to continue disregarding the public and also is an indicator of the limited use maps are put to. Unless the

government relaxes rules regarding access to maps, there is little possibility of GIS ever gaining ground in India.

Electronic map data: SOI still is predominantly a manual map-producing organization, although it is now preparing for electronic production of maps. Clearly it will be many years before all map features of the entire country can be digitized. However, it is time to consider imminent problems that will arise with the change in the medium of map production. These relate to certification of the international boundaries of India by SOI of all maps published in this country. This is a legal requirement at present. Would SOI's right to inspect for certification extend to machine readable maps produced by other agencies too, though digitized from SOI toposheets? There would also be the need to ensure a certain degree of accuracy of the data. Who should be responsible for ensuring that strict standards are observed in digitizing maps?

Another point to consider is whether it is necessary for a user to wait for very accurately digitized and certified maps? Under the present circumstances, the greatest emphasis should be on rapid large scale digitizing of maps. But all these maps need not necessarily have the degree of accuracy that is essential for the purpose of producing topographic maps. It is important to make a distinction between very accurate maps such as those useful for military purposes and those which are less so, but equally useful for many other purposes, such as in regional planning.

A GIS resource centre: There is no reason to suggest that a new institution be set up for the propagation of GIS. Institutions interested in planning and administration can take on these functions. But an institution devoted wholly to the study, development and application of GIS may be the answer to attracting long term commitments from GIS vendors, developers and specialists. My feeling is that such a centre could bridge the gap between developers and users. Today, in this country, there seems to be very limited communication between those who develop GIS software and those who may ultimately use them. This has resulted in the creation of software that is poorly designed and often inadequate. Such a centre would also be ideal for rapidly digitizing maps for users.

There is also a need for an advisory body to inform potential administrators and operators of GIS on the sources of hardware, software and training available in the country. There is need for information on capabilities of different software packages for meeting specific requirements. A resource group on GIS could advice on the probable sources of map data, suitable map scales to be used for different purposes, budgeting and time scheduling for different kinds of work. Although it may not have any regulatory functions, it can still play a very constructive role in promoting GIS in the country.

CONCLUSION

There is an urgent need for all those who are interested in the

future of the development of GIS in India to clearly define the parameters within which one can work. There has been a great degree of suppression and control exercised on maps and data by the government so far, and it is quite clear that without easing control over these, GIS cannot flourish. Many of these controls are unnecessary today with the major changes that have taken place in the methods of data capture and Information Technology. However, this is not reflected in the government's attitude towards the restriction of the public's access to topographic maps.

At present, the active use of GIS is mainly in specialized government institutions such as the Indian Space Research Organization. This tendency is further consolidated by the development of locally manufactured systems for the analysis of remotely sensed data (viz., ISROVISION). It is important for the policy makers to appreciate that there is great scope for both macro and micro-level physical planning in the GIS environment using map and government departmental data that is already available.

The high cost of hardware and software is another reason for the limited use of GIS in India. Keeping in mind the economic situation, it is suggested that international software vendors not only have representatives in the country but also consider marketing their products at more realistic prices. Stress should now be given to developing inexpensive user-friendly software, even perhaps with limited capabilities. This would ensure a larger user community than at present.

Finally, there can be no surrogate for skilled GIS operators. Much effort needs to be directed towards their training. Emphasis should be placed on increasing productivity and improving the quality of information that is generated from data in a GIS environment.

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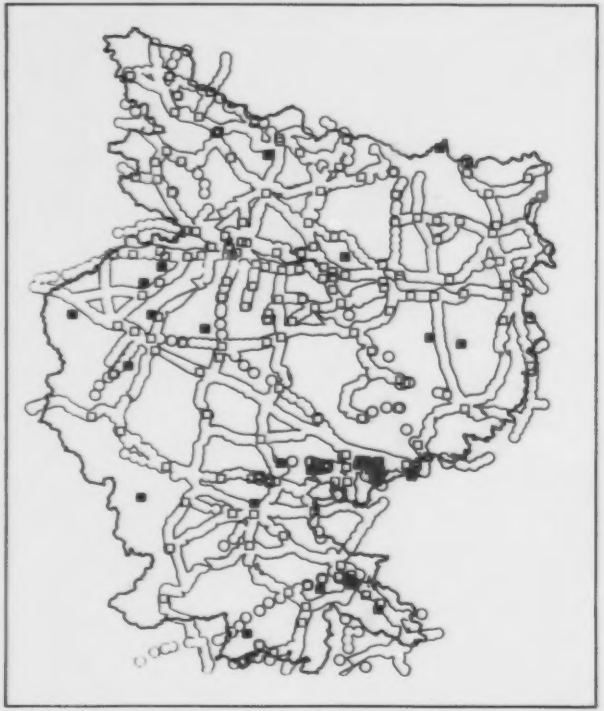
MAP 2



ACCESS OF CITIES AND TOWNS TO HIGHWAYS AND RAILWAY STATIONS 1986

5 Km buffer along highways and stations

Town outside buffer

Town inside buffer

One hundred and ninety-eight towns are within five kilometers of a highway or a railway station. The remaining twenty-one are mostly small towns.

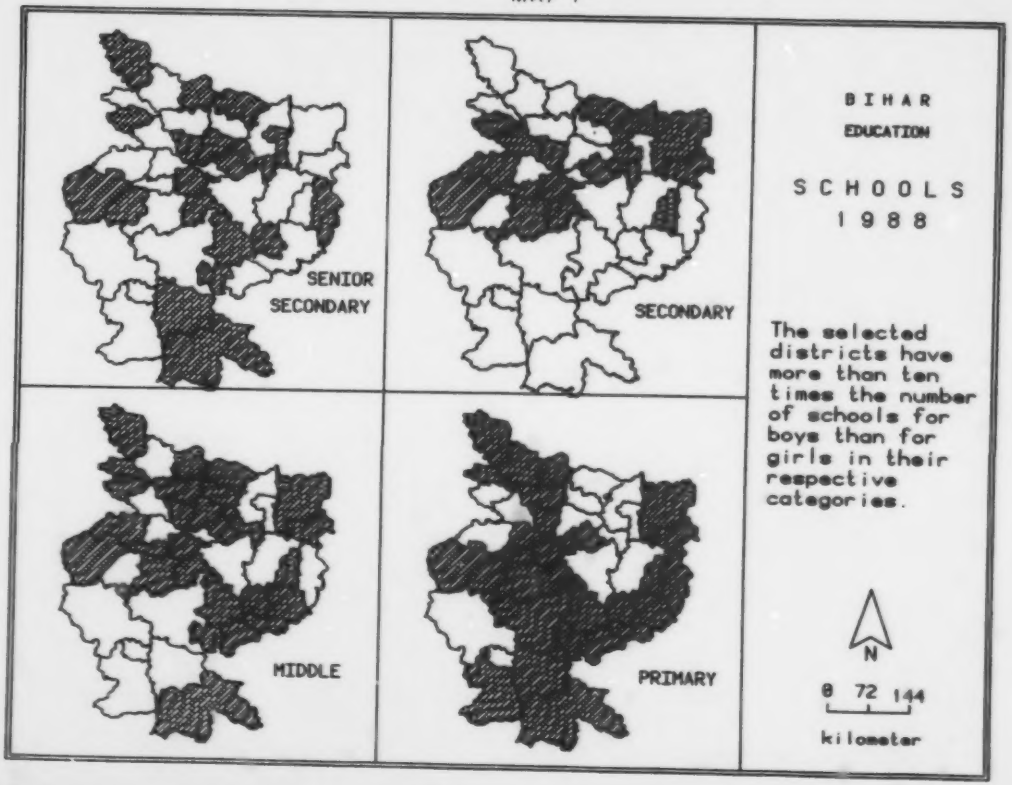
N

0 38 78

kilometer

726

MAP 1


SENIOR SECONDARY
SECONDARY
MIDDLE
PRIMARY
BIHAR
EDUCATION
SCHOOLS
1988
The selected districts have more than ten times the number of schools for boys than for girls in their respective categories.
N
0 72 144
kilometer

A FLOOD DISASTER INFORMATION SYSTEM AND ITS APPLICATION

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ABSTRACT

The paper describes the conceptual framework and design characters of creating Flood Disaster Information System(FDIS), and its application experiences in China. The FDIS includes three parts of spatial database, application oriented models and user interface, which developed based on natural environment conditions, for example the landform features in study area. The database should be updated in time. Before flood peak period, processing remotely sensed data and collecting statisitic data to update the database, and during flooding period, using airborne radar to monitor the flooded area, are our primary experiences in creating and using the FDIS.

During the 1991 flood disaster in China, The system and related techniques was used to Huaihe River of Middle China and Taihu Lake region of east China for tracing the flood process and evaluating the flood damage losses timely.

1. The Need For a FDIS

Each year, floods take an increasing number of lives and property. Single events can result in heavy toll of death and property damage, as in Sichuan of China, flood of 1983, when more than 1,300 died,, 1.5 million were left homeless, and damage totaled 1.1 billion, also in 1991 flood disaster of China, based on incomplete statisitics, 1729 died, 650,000 houses destroyed and damage losses counted up to 39.8 billion yuan[Chen, 1991].

Flood damages are caused not only by rain but also by man-made change to earth's surface: farming, deforestation and urbanization, for example. These actions increase runoff from rains and produce sediment deposited in river and lake bed which reduce the storage capacity of them, that previously would have caused no flooding inundate vast areas today. In Dongting lake region of China,the riverine alluvial plain round lake have been surrounded by more than 5,000km dykes, the sediment deposited in lake bed make its capacity reduce 40% from 1954 to 1983. Each year, the region faces the flood disaster which has become a hinder factor of regional development.

Système d'information sur les inondations catastrophiques et application

RÉSUMÉ

Le présent article décrit le cadre de travail conceptuel, les caractéristiques de conception et les expériences d'application du système d'information sur les inondations catastrophiques en Chine.

Le système d'information pour le contrôle des crues comprend deux parties - modèles orientés sur les applications et base de données spatiales - qui ont été élaborées selon la principale composante du milieu naturel, par exemple les caractéristiques géomorphologiques et le système socio-économique, comme le comportement des équipes d'intervention, dans la zone à l'étude. La base de données sera mise à jour selon les besoins. Nos premières expériences de création et d'utilisation du système d'information : avant la période de crue, à l'aide de données de télédétection pour obtenir des données statistiques et sur l'utilisation des terres afin de mettre à jour les données d'attribut et durant la période de crue, à l'aide de données radar aéroporté pour surveiller les zones inondées.

Grâce à de l'aide du CRDI, un système d'information sur les inondations catastrophiques a été créé pour la région du lac Dongting (SIG - lac Dongting), et a été utilisé par le ministère des ressources en eau de Chine et le gouvernement local de la province de Hunan, lors des activités régulières de lutte contre les inondations et appliqué également à d'autres domaines comme l'agriculture, l'aménagement régional, etc.

Durant l'inondation catastrophique de 1991, la technologie du SIG - Dongting a été appliquée à la rivière Huai He du centre de la Chine et au lac Taihu de l'est de la Chine pour tracer la progression de l'inondation et évaluer les dommages de manière rapide et précise.

Except the above causes, poor flood management, failure to control flooding, delaying disaster relief and unsuitable recover alternatives also will contribute to the damages. The damages of 1987 flood in Liaohe River of China was reduced 50% compared with the damage in 1985 because the microwave communication system had been established since 1985 flood.

Alleviating the harmful effects of floods requires actions on three aspects: structure schemes to protect human settlements and residences from flood damage, reducing the vulnerability of human and local / national economics, and improving flood management level. China, with press of population, does not use the second action, in contrast, most floodplains have been developed for their fertilized soil and convient transportation.

To improve the level of flood management, the decision-makers require timely information about flood conditions, damage losses, and socio-economic characters in flooding area, etc. The FDIS is of meeting these requirements.

2. The Conceptual Framework of Creating FDIS

Based on the environmental background and damaging ways in flooding area, various regional flood types can be divided into torrents, dam break, urban flood, overflowing, waterlogging and bursting. The former three types only damage some area and are the research topics in next five years. The later three types usually occur in lower reach and delta of rivers of east China, and in the downstream and delta plain of Guanga, Ayeyarrwady and Mekong in south Asia. In east China plain, there are developed economics, density population, and about 100 municipalities facing serious flood problems, Tianjin, Shanghai. and Wuhan for example. If the flood occured, the damage whould be huge. The FDIS has been established for three flood types in Middle reach of Huihe River, Dongting Lake region in Middle reach of Yangtze River and Lower Yellow River separately. And the techniques from FDIS is being transferred to Bangladesh.

The FDIS is a technique system of multi-level and multi-application objectives, involved in resources development and environment protection in whole watershed.

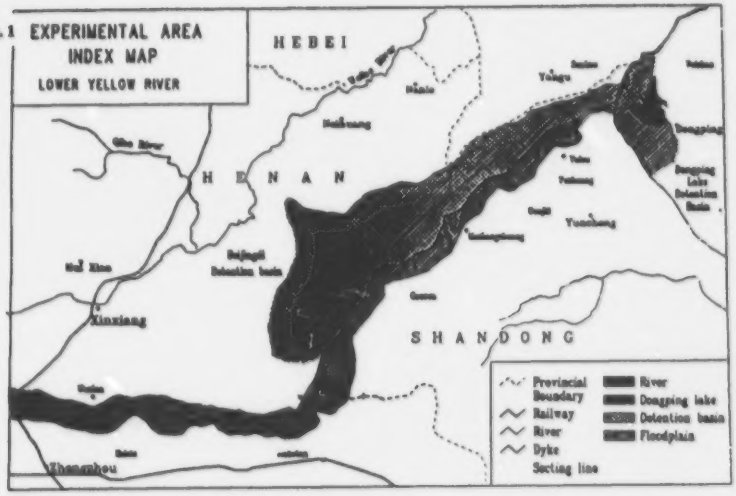
(1) Watershed view It is necessary to build the FDIS from watershed angles instead of confining to local problems. Taking the lower reach of Yellow River as an example, the storm runoff and soil erosion in middle reach of the river and the Loess plateau are the main causes of flood, so the ice / snow prediction model in upper reach, water and soil conservation model in Loess Plateau, and the runoff model in middle reach are integrated into

the FDIS of the lower Yellow River. And monitor data from 25 meteorological automatic observation stations, 65 precipitation stations, 2 radar systems for observing rain and other routine observation stations were transimitted into the system by micro-wave communication. Based on these data and model, the system can timely predict the flood process, estimate the inundated area, etc.

(2) Regional analysis The physiographical phenomenous and environmental change features of the study area were taken as the basis of creating FDIS. By landform and landscape analysis, the environmental and anthropogenic landform and their evolution processes will determine the contents and structure of spatial database. In lower Yellow River, 14,000km embankments along two sides of the river restrain the flow to river bed, which is above ground elevation. If it is so, the river bed is not very stable and main river course often sways inbetween embankments. The works of flood control in there is for keeping the embankments safe from bursting. The study area of the FDIS is the river bed and the most data structure, stored in river segments, is vector(Fig. 1)[Chen Shupeng, et.al 1990, Vol.1]. Therefor, in Dongting lake region of Hunan province, the landform is characterized by dyke-surrounded area and lake is going to die for sediment deposited. The goal of flood control is of protecting DSA safe and reducing the losses of flood diversion. The database of Dongting lake GIS reflected the DSA and island units(Fig.2)[Chen Shupeng et.al 1991, Vol.2].

(3) Application oriented The overall objectives of creating FDIS is for reducing the disaster losses by providing information support, required by decision-maker and experts on flood control. To meet the information requirement, the system should be able to timely afford field conditions of flood events. Also in Dongting lake region, the problems of interest to decision maker, who intend to mitigate the losses to minimum, are when and where the flood in lake and river should be diverted, the diverting discharge and hydrograph, inundated ranges, depth and last time, also are the population and property existed in flooded area, so the flood wave model is a basic model in FDIS.

(4) Real-time updating The key to build an operational FDIS is real time ensurence of the information source and its integrated utilization. The meteorological satellite can furnishes evidence to arrange aerial remote sensing monitor. The image form aerial real and synthetical aperyture radar can meet the needs of all weather monitor during flooding period, and can be used to extract the ground information on settlements, dykes, flooded area and so on, that some of them will be used to update the database. The remotely sensed data from satellite, such as TM, SPOT, etc. can be used to dectect the landuse change,, delineate the flooded area and update the thematic data of spatial database. With the development of socio-economics, the statisitic data in database also need to be



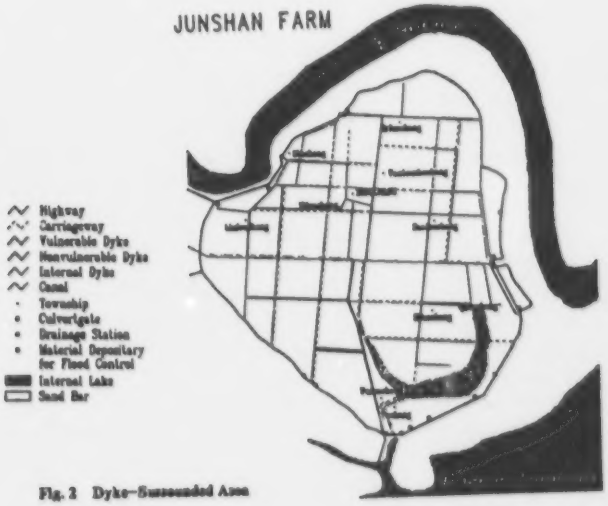


Fig. 2 Dyke-Surrounded Area

updated.

3. The Design Characters of FDIS

In general, the FDIS consists of three subsystem: the database, model and user interface. Fig 3 is the structure and components of River Flood Control Information System in Lower Yellow River[Zhou, C.H. 1991].

(1) Digitial elevation model Those data and results that flood control, agricultural planning and regional management rely on are from DEM, for example,the storage capacity of rivers and lakes, lake beach area at different interval elevation, lake degratation rate, flood wave simulation, loss estimation and so forth. Therefor, DEM is base data of FDIS. Otherwise, the flood plains usually are low-land with smooth terrain. The DEM must fully reflect the changes of micro-terrain. In Dongting Lake GIS, funded by IDRC of Canada, the grid sizes of DEM are 50m * 50m for whole region and 25m * 25m for DSA(Fig.4)[Chen Shupeng, et.al 1990, Vol.2; Wan Qing,et.al, 1991].

(2) Statisitic data These data is the basis of flood damage losses estimation. But the flooded area is inconsistent with administrative boundaries, which require the data in system has spatial locationn. In Dongting lake GIS, the data were collected for each settlement, including population(male, female, children, olders,etc.),agricultural and industrial value, cultivated area, landuse pattern, crops, safe facilities, building quality, and so on. Each data has a geographic coordinate and is linked with spatial database. The collecting and updating of statisitic data is a hard work of time and money consuming, which has been a routine work of local flood control agency.

(3) Real time monitor and transimission The flood process is measured on hours, for instance,the moving time from Sanmen Gorge reservoir of the Yellow River to Zhengzhou, capital of Henan province,is about 22hs. The time is very important, which requires timely monitor of flood conditions and quickly transimission of information on flood fields. The aerial remote sensing has been used to monitor the flooding proces and investigate the flooded area. The image is transimitted to receiving station(Fig. 5)[Jiang J.S. et.al 1991] for visualization of decision makers and experts on flood control, that spent 4 hours for monitoring the 1991 flood disaster in Huaihe River, and for extraction of flooded area. The results were merged with thematic and statisitic data in spatial database for estimating the losses. The spacial remotely sensed data can be used to investigate the inundated ranges if the satellite just pass the region in flooding days. It take several days in processing the data and estimating the losses if the spatial database existed.

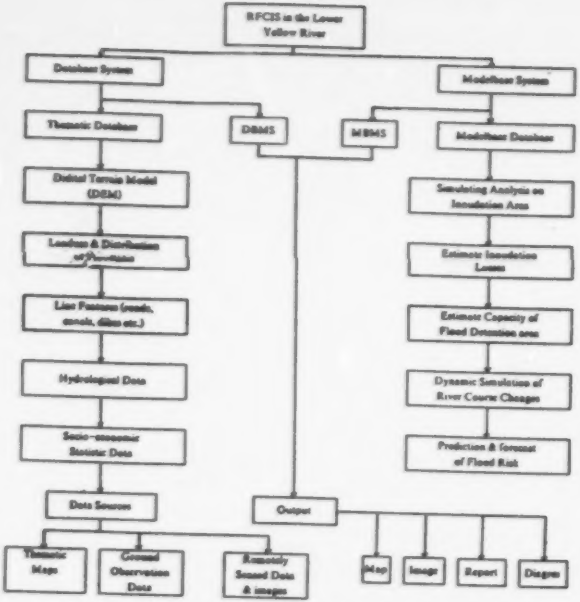
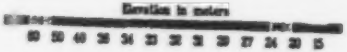


Fig. 3 The Structure and Components of RFCIS in the Lower Yellow River

Fig. 4 DEM of DSA



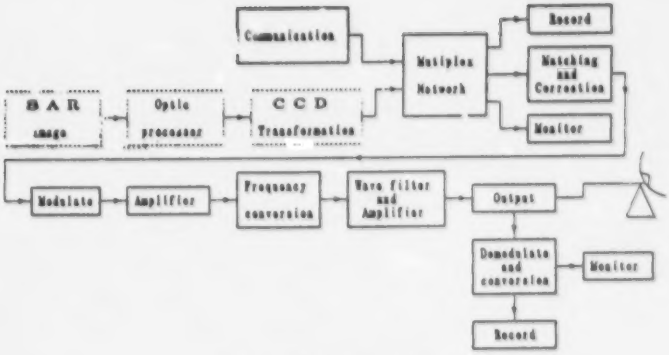


Fig. 5 SAR Image Transmission

(4) Two dimensional flood wave model To evaluating the potential losses of diverting flood and the feasibility of evacuation alternatives, it is necessary to predict the diverting hydrograph of discharge and the water surface profile. Flood diversion area usually is a plain. The one dimensional model of unsteady, open channel flow is not suitable, instead of using two dimensional model. In Dongting lake GIS, the model has been applied to Junshan Farm flood diversion area(Fig. 6)[Wu Bingfang,1991]. The model retrieves the DEM data from database and the roughness coefficience specified from landuse types.

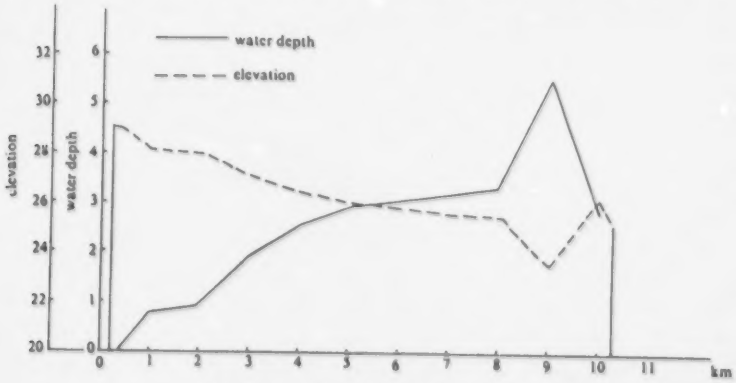


Fig. 6 Profile of Water-Depth and Elevation

(5) Estimating damage losses This is the main goal of FDIS. only when the

decision-makers, namely Ministry of water resources and Ministry of civil affairs in central government of China, timely acquire the reliable information on flooded area, property and population, can they take effective measures to do disaster relief for minimizing the potential losses. Nowdays, the FDIS only afford the flooded area of cultived land, property and population in different water depth, and flooding last time. It did not give acutal losses, which is the research topic in next five years.

4. Application Experiances

(1) 1991 flood disaster of China The floods occured in 1991 are disaster for Chinese people and government. the flooded area covered Anhui,Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Sichuan, Zhijang provinces and north-west mountainous region of Beijing, which caused 1700 or more dead and damaged about 39.8 billion Yuan. But for the FDIS, it is a good opportunity to test system and techniques.

In middle reach of Huaihe River of Anhui province, flood disaster occurs for 2 times in every three years because of limited discharging capacity in downstream. There are 64 flood detention and diversion area on two sides of the river. when flood peak level exceeded the limit level,the flood in main course should be diverted. The FDIS for each flood diversion area was built in 1990, and used in 1991 flood disaster periods. The DEM from aerial photogrametry, landuse extracted from aerial image, and statisitic data on settlements are combined into spatial database. The FDIS is a integrating system of database and flood wave model and victim evacuating simulation model under the management of user interface. From May to July of 1991, the diversion decisions were made for two times. In this case, the two dimensional flood wave model was used to trace the diverting process which afforded real time information on inundated area, depth and so on. At the same time, the evacuating model simulated the retreating steps for identifying how many people still were in the flooding area. The spatial database was used to retrieve the flooded area, population and property in half hours by integrating with aerial SLR image and simulating results.

Taihu lake region of east China, located in Shanghai, north-east Jiangsu and north Zhijang, is a depositing basin with average elevation of 2 to 5m above sea level. The region has a very developed economics. The flood event is unusual and the FDIS was not built. But during the flooding periods of 1991, the flood peak level was 4.78m, 0.44m higher than the highest level in history. It only spent 13 days on creating the spatial database, which contains river system, DEM, landuse, administrative boundaries and statistic data based on districts. The TM and SLAR image was used to extract the flooded area with digital image processing and visual interpretation. The flooded area in Taihu lake region is about 8.23 million mu, in which no any harvests is 1.35 millions mu. Comparing with the flooded area

of 15 million mu, declared by local government, the FDIS afford more precision losses data, and finally the local and central government agreed the FDIS' data.

The precipitation, flood volume and peak discharge of 1991 disaster periods in Taihu lake region were less than 1954, but the flood peak level is 0.48m higher. The causes were of disrupting agricultural eco-system. For example, since 1954, most of small canals were blocked because farmers did not dig the silt in canal beds used as fertilizer, instead using the chemical fertilizer. On the other hand, the vulnerability of population and property has been rapidly increased in last 40 years, but the criteria on preventing flood still remained low, that was another causes of huge damage losses.

(2) Dongting lake region locates in the downstream of planning Three Gorges dam of Yangtze River. Once the dam built, it certainly will afflect the eco-environmental conditions of the region. The Dongting lake GIS created, funded by IDRC of Canada, will be the basis of assessing the impacts of dam on groundwater and swamping land, furthermore, simulating the impacts on the procession of lake degradation, on the speed of scouring and depositing in Jingjiang reach bed, and analyzing the impacts on bursting risk of the embankments along the river and dykes round lakes. In the successive project of Dongting lake GIS, these are the main research topics.

(3) The expertises / experiences of creating FDIS has been transferring to Bangladesh floodplain where face the similar flood problems as Dongting lake region. Funded by ESCAP / UNDP, the joint project on application of remote sensing and GIS to Bangladesh floodplain and flood monitor started in 1989. The pilot FDIS will be transferred to SPARRSO of Bangladesh.

5. Conclusion

The research on FDIS started in 1983, and only focused on the major flooding region, i.e. Dongting lake region, Lower Yellow River, and Middle Huaihe River as case studies of three flood types. There are still a lot of academic and organization problems waiting for solving, for example the integrating of GIS, database,remote sensing and analysis models, and the interface with decision makers. In next five years, the techniques will be extanded to other flooding region over the China and other flood types, and the achievments from creating FDIS will be perfected as a decision support system on flood control and management for central and local governments. The 1991 flood disaster of China will quicken this step.

Acknowledgements

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GÉNÉRATION D'IMAGES GÉOCODÉES PAR CONTROLE GPS POUR L'INTÉGRATION DANS UN SIG

GPS IMAGE GEOCODING FOR GIS INTEGRATION

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RÉSUMÉ

L'incorporation d'images satellites dans un système d'information géographique exige que chaque pixel soit géoréférencé dans un système cartographique ou géographique. Pour ce faire, il est nécessaire d'insérer des points de contrôle identifiables ayant des coordonnées connues au sol. L'étude montre les différents résultats obtenus en utilisant trois sources différentes pour l'acquisition des coordonnées des points de contrôle pour la corrections des images SPOT-HRV. Les coordonnées sont soit extraites d'une carte topographique 1:50 000, soit obtenues à partir de coordonnées compensées dans un bloc d'aérotriangulation ou soit déterminées par des mesures GPS au sol. Les résultats de précision sont évalués sur des points de vérification connus ayant fait l'objet de levés GPS précis par le Centre canadien des levés. L'objectif visé par ces diverses manipulations est de mettre au point une procédure d'acquisition de points de contrôle peu coûteuse, accessible par des non-spécialistes en géodésie et ayant le niveau de précision requis pour l'extraction de données topographiques numériques à l'échelle de 1:50 000.

Le rééchantillonnage des images est basé sur la modélisation précise des paramètres orbitaux, des erreurs du capteur et des distortions terrestres. Les résultats démontrent que, pour corriger géométriquement une image avec une erreur quadratique moyenne inférieure à 10 mètres, les points d'aérotriangulation doivent posséder une erreur inférieure à 4 mètres. De plus, les ortho-images produites à partir de points d'appui cartographiques ne possèdent pas la précision planimétrique pour une donnée de position au 1:50 000. Finalement, en l'absence de coordonnées photogrammétriques, les ortho-images produites à partir de points d'appui GPS montrent l'efficacité et la rentabilité de l'utilisation de tels récepteurs. Ceux-ci doivent posséder une précision supérieure à 5 mètres pour l'acquisition de points de contrôle lors de travaux nécessitant l'intégration de données dans un SIG.

ABSTRACT

Integrating satellite imagery in a Geographic Information System (GIS) demands that pixels be georeferenced in a geographic or cartographic coordinate system. This is achieved with Ground Control Points (GCPs) which can be accurately identified on the image and for which ground coordinates are known. The study reveals the results obtained with three different GCP coordinate acquisition sources to correct SPOT-HRV images. Coordinates are either read from a 1:50000 map sheet, from compensated data in an aerotriangulated bloc, or determined by GPS surveys. Accuracy results are evaluated with precise surveyed check points done by the Canada Centre for Surveying. The main goal behind these various manipulations is to offer a GCP acquisition procedure which is inexpensive, available to the

non-specialist in geodesy and that can render the needed accuracy level for digital topographic data extraction at a 1:50 000 scale.

Resampling of the image is based on rigourous modeling of satellite orbital parameters, sensor errors and terrestrial distortions. Results indicate that to geometrically correct an image with an RMS accuracy smaller than 10 metres, photogrammetric control points must have an accuracy of 4 metres or better. Furthermore, ortho-images produced with map control points are not accurate enough for positional data extraction at the 1:50 000 scale. When photogrammetric data is not available, ortho-images produced with GPS control points confirm the cost efficiency of using such receivers. GPS receivers must have a planimetric accuracy greather than 5 metres for GCP acquisition in applications needing satellite data integration in a GIS environment.

INTRODUCTION

Les systèmes d'information géographique (SIG) sont des outils très utilisés dans le domaine de la géomatique car ils permettent d'intégrer diverses sources d'information. L'intégration exige cependant que ces différentes données détiennent une base commune liée à leur référence spatiale. De plus, chaque source de données doit être représentée géométriquement avec une précision similaire pour permettre une analyse comparative valable et conserver un homogénéité entre les informations. Ainsi, lors de l'intégration d'images satellites dans un SIG, on doit procéder préalablement à la correction géométrique de ces images et à la transformation de leurs systèmes de coordonnées (pixel,ligne) sur une projection cartographique. Pour procéder à ces transformations, on doit utiliser des points identifiables au sol pour lesquelles on peut déterminer les coordonnées images et les coordonnées cartographiques. Ces points portent le nom de points d'appui ou de contrôle. Les médiums couramments employés pour la détermination des coordonnées de ces points sont :

1- les cartes topographiques (support physique ou numérique);
2- les fichiers d'aérotriangulation contenant des points photogrammétriques compensés numériquement.

Le Centre canadien de géomatique a entrepris, dans le cadre du projet SINAPS (Système INtégré d'Acquisition de données Par Satellite) de comparer ces différentes techniques d'acquisition de données pour la rectification des images SPOT-HRV [Clavet, 1991]. Ils ont comparé leurs résultats à des observations GPS (Global Positioning System) pour établir quelles sources d'acquisition des points de contrôle conviennent le mieux pour l'extraction de données topographiques à l'échelle du 1:50 000.

Le présent projet complète l'analyse entreprise dans SINAPS en ajoutant des variables supplémentaires telles que le coût, la durée et l'accessibilité. Pour cette raison, on se référera et comparera souvent à l'approche que les personnes de SINAPS ont employé et les résultats qu'ils ont obtenus.

OBJECTIFS

L'objectif général de ce travail est de mettre au point une procédure d'acquisition de points de contrôle peu couteuse, accessible par des non-spécialistes en géodésie et ayant le niveau de précision requis pour l'extraction de données topographiques numériques à l'échelle du 1:50 000. Les résultats nous permettrons d'évaluer l'influence de la précision des points d'appui sur l'exactitude des corrections géométriques. De plus, nous pourrons comparer trois sources pour l'acquisition des coordonnées des points de contrôle:

- la carte topographique 1:50 000;
- le fichier d'aérotriangulation contenant des points photogrammétriques compensés numériquement;
- et des mesures GPS au sol.

L'ensemble du travail vise spécifiquement à évaluer la performance d'un récepteur GPS peu dispendieux et rapide à utiliser pour le positionnement de points de contrôle au sol. Et enfin, de valider l'intégration multisources dans un SIG par l'intermédiaire d'ortho-images précises nécessaire lors de travaux de précision (ex: mise à jour de cartes topographiques au 1:50 000)

MÉTHODOLOGIE

1- Captage des coordonnées des points de contrôle sur le site d'essai

La zone d'essai de Sherbrooke a été choisie pour les applications topographiques de la télédétection [Lasserre et Lemieux, 1990]. La figure 1 est scène entière (60 km x 60 km) d'une image SPOT-HRV panchromatique prise en juin 1987 de cette région. Elle nous indique de plus la distribution des différents points de contrôle et de vérification utilisés dans ce projet. La zone encadrée englobe la moitié nord du feuillet SNRC (Système National de Référence Cartographique) 21E/4 et la moitié sud du feuillet 21E/5 pour une couverture d'environ 26 km x 40 km.

Ce site a déjà fait l'objet d'un levé précis GPS par le Centre canadien des levés [Clavet, 1991]. Des récepteurs GPS Ashtech avec une précision de 50 cm ont été employés pour la détermination des coordonnées de 31 points situés sur des intersections routières. Les coordonnées de ces même points ont de plus été déterminées par des lectures sur une carte au 1:50 000 ainsi que par des lectures sur un fichier numérique de données topographiques. Ces mêmes points ont également fait l'objet d'un travail photogrammétrique permettant de produire les coordonnées X, Y et Z de ces points à partir d'un fichier d'aérotriangulation obtenu par la construction de modèles stéréoscopiques de photographies aériennes (appareil de restitution de premier ordre).

La dernière méthode d'acquisition des points de contrôle a été réalisée par de nouvelles observations GPS à l'aide d'un récepteur plus simple utilisant uniquement un canal de réception avec le code C/A seulement (Clear Access ou Course Availability). Il faut mentionner qu'un récepteur multicanal utilisant le code C/A de la phase porteuse ou bien Doppler comme le Ashtech améliore grandement la précison des lectures GPS [Ashjaee, 1986]. Cependant de tels récepteurs sont plus dispendieux et exigent une procédure d'acquisition et de traitement plus rigoureuse. Le récepteur GPS utilisé est le MAGELLAN NAV 1000 PRO qui mesure la pseudo-distance entre la station d'observation et chaque satellite de la constellation [Magellan, 1990]. Pour déterminer la position exacte en X et Y, nous avons besoin d'au moins 3 satellites et de l'altitude de l'antenne pour résoudre le modèle mathématique [Leick, 1990; Milliken and Zoller, 1980]. La figure 2 est un schéma

illustrant les diverses étapes menant à la détermination des coordonnées cartographiques à partir d'observations GPS [Lasserre and Pouliot, 1990].

Les spécifications de MAGELLAN nous indiquent que l'on peut espérer obtenir une précision de l'ordre de 15 mètres en mode autonome et de 5 mètres en différentiel avec un minimum de 32 lectures consécutives. En raison de certaines contraintes logistiques et temporelles, nous n'avons pas été en mesure de relever les 31 points utilisés lors du levé avec le Ashtech. De plus, lors de la manipulation des récepteurs, une erreur s'est introduite dans la lecture de l'élévation d'un point ce qui a réduit encore le nombre d'observation valable pour l'analyse. Nous avons donc fait la correction géométrique des images SPOT-HRV à l'aide de 11 points de contrôle.

2- Application du modèle de correction géométrique

La correction géométrique à été réalisée par l'intermédiaire du logiciel SRIT (Système de Rectification d'Images en Teledétection) développé conjointement par le Centre canadien de télédétection et le Centre canadien de géomatique [Savopol et al., 1991; Toutin et al., 1990; Toutin et Lemieux, 1991]. Ce logiciel est basé sur la modélisation précise des paramètres liés à la géométrie totale de prise de vue (orbite, capteur, terre). Il utilise notamment des informations spécifiques du satellite et de l'image telles que la longitude, la latitude, le temps, l'angle de prise de vue, etc... ainsi que les données d'éphémérides décrivant la position et la vitesse du satellite et les données d'attitude liées au variations angulaires [Toutin et al.,1990]. La modélisation est l'expression des équations de colinéarité et de coplanarité aboutissant à un système de 8 inconnues par image [Toutin, 1986]. Le rééchantillonnage de l'image se fait à l'aide d'un modèle numérique de terrain permettant de tenir compte des variations d'élévation. Pour permettre d'asseoir le modèle mathématique, on doit utiliser des points d'appui connus dans un système de référence cartographique. La précision de ces points d'appui ou de contrôle influencera dans une certaine mesure la précison planimétrique de l'ortho-image produite. Toutin et Carbonneau (1989) ont obtenu une précision de l'ordre du tiers de pixel pour des ortho-images construites avec les données SPOT. Toutin (1990) a de plus estimé que son modèle mathématique possédait une précision interne inférieure à un mètre.

RÉSULTATS

La première étape d'analyse a été faite en comparant les divers jeux de données aux coordonnées GPS Ashtech qui ont été rattachées au réseau géodésique. Ces coordonnées sont considérées les valeurs les plus exactes (50 cm) et elles serviront comme base commune de comparaison. L'écart-type des différences entre la valeur Ashtech et la valeur mesurée a été utilisée pour comparer et déterminer la précision planimétrique des différents types d'acquisition des points de contrôle. Le tableau 1 présente les erreurs des coordonnées des points pour chaque source de contrôle. On remarque à première vue, que les points issus de l'aérotriangulation possède la meilleure précision soit une erreur planimétrique de 3.2 mètres Il faut mentionner que cette précision est dépendante de la qualité du bloc d'aérotriangulation de la région de Sherbrooke qui est construit suivant un contrôle géodésique de premier ordre. Au Canada on retrouve des blocs avec une qualité pouvant varier d'excellent à médiocre. On constate, de plus, que la précision du contrôle cartographique (38 m. pour p=90%) diffère des normes de précision de la carte au 1: 50 000 qui est de 25 mètres pour une carte A-1 pour une probabilité (p) de 90%. Les précisions GPS en mode différentiel et autonome sont également de l'ordre de grandeur données par le manufacturier. On peut noter que la très bonne précision des observations en mode autonome (9.2 mètres) est le fruit du hasard et

qu'on ne peut espérer obtenir d'aussi bon résultat à une fréquence élévée car la qualité du signal est variable et elle est contrôlée par le Département de la défence des Etats-Unis.

Après avoir corrigé géométriquement l'image SPOT-HRV avec les divers points d'appui, l'étape ultime pour la validation des résultats est de comparer numériquement les différences sur des points de validation indépendants. Une routine du logiciel SRIT permet d'utiliser des points de validation permettant à l'usager d'introduire des coordonnées vraies (GPS Ashtech) et de les comparer au coordonnées estimées par le modèle. L'erreur moyenne quadratique (EMQ) calculées sur les points de validation Ashtech a été utilisée comme base commune de comparaison. A des fins cartographiques, 90% des points doivent rencontrer les normes de précision de la carte. Pour ce faire, on utilise la précision circulaire planimétrique CMAS (Circular Map Accuracy Standard) qui se calcule comme ceci :

$$CMAS = \sqrt{(EMQ_x^2+EMQ_y^2)} * 1.5174$$

Cette erreur finale comprend l'erreur des points d'appui, l'erreur du pointé sur l'image (1/3 pixel), les erreurs du MNE, les erreurs de rééchantillonnage et l'erreur interne du modèle (1 mètre). Cette erreur doit tendre vers l'erreur tolérée pour la stéréonumérisation de données topographiques à l'échelle du 1:50 000 qui est de 10 mètres. Le tableau 2 présente les EMQs et le CMAS des ortho-images construites à l'aide de 11 points d'appui. Les EMQs sont calculées sur 16 points de vérification GPS Ashtech. L'image corrigée à l'aide des points GPS Ashtech a obtenu les meilleurs résultats. Cependant, les écarts de précision entre les ortho-images produites à partir du levé Ashtech, du fichier d'aérotriangulation et du levé différentiel Magellan ne sont pas significatifs. Une analyse statistique plus approfondie confirme que ces trois images ont une forte inter-corrélation (.996) et que leurs contenues est similaires et comparables. Les ortho-images corrigées à l'aide des points issus du levé autonome Magellan et de la carte topographique obtiennent des résultats de précision ne respectant pas les normes pour la carte au 1: 50 000. Ces ortho-images sont grossièrement 40% de moins bonne qualité que celles produites avec le fichier d'aérotriangulation. La figure 3 nous montre la distribution spatiale entre la précision planimétrique des points d'appui et la précision de l'ortho-image résultante. On remarque que lorsque la précision planimétrique est inférieure à environ 6 mètres, les écarts entre les précision des ortho-images ne sont pas significatifs. Au delà de 6 mètres, la précision planimétrique influence davantage la précision des ortho-images car les écarts s'accentues rapidement.

Finalement pour évaluer l'efficacité des différentes sources pour l'acquistion des points de contrôle, nous avons évalué les temps requis et les coûts impliqués pour chaque méthode. Le tableau 3 montre le temps d'acquisition, le temps de traitement et les coûts estimés pour le jeu de données de Sherbrooke. Le temps d'acquisition correspond au temps nécessaire pour le captage de 31 stations. Le temps de traitement, quant à lui, inclus le temps pour l'épurage des points, la transformation dans un système de référence commun, la compensation, etc... qui mène aux coordonnées introduites dans le modèle SRIT. On constate que les approches cartographique et photogrammétrique sont les plus rapides et que se sont elles qui nécessites le moins d'intervention de la part de l'usager. Les travaux GPS demandent beaucoup plus de préparation et de planification. Cependant le récepteur Magellan est de loin plus rapide et simple à manipuler que le récepteur Ashtech. Par exemple, le temps d'observation du Ashtech est en moyenne de 1h30 par station alors que pour le Magellan, il se situe au environ de 10 minutes par station. Étant un récepteur portatif, le Magellan permet, de plus, une mise en station instantanée ce qui est très utile pour le levé d'intersections routières denses et dangereuses.

CONCLUSION

L'hypothèse de départ supposant un lien direct entre la précision des points d'appui et la qualité de l'image résultante s'avère légèrement fausse. En effet, on constate que l'influence de la précision planimétrique des points de contrôle ou d'appui n'est pas significatif dans toutes les circonstances. Dans la présente étude, c'est-à-dire pour la correction des images SPOT-HRV avec le logiciel SRIT, la précision des points de contrôle n'est pas un facteur majeur pour la précision des ortho-images introduites dans le SIG pour des points ayant une précision meilleure que 5 mètres. En effet, la précision du modèle mathématique de correction géométrique et le type d'ajustement compensent pour les erreurs introduites par les points de contrôle. Il n'est donc pas nécessaire d'employer des outils de haute précision (précision < 3 mètres) comme le GPS Ashtech lors de la collecte des coordonnées des points de contrôle car le haut niveau de précision n'apporte aucune amélioration notable. Les ortho-images corrigées à l'aide des points issus du bloc d'aérotriangulation, du GPS Magellan différentiel et du GPS Ashtech respectent toutes les normes de précision pour la carte au 1:50 000 soit 10 mètres. Des points de contrôle avec une précision moins bonne que 6 mètres comme pour la carte et le GPS en mode autonome ne sont pas recommandés pour la correction géométrique d'images satellites lors de l'intégration dans un SIG car l'image résultante ne respecte pas les normes pour la carte au 1:50 000.

Il est difficile d'identifier la meilleure méthode car celà dépend des besoins de chacun. Cependant pour des travaux de précision nécessitant l'intégration de plusieurs sources d'information à une image satellite dans un SIG, l'approche photogrammétrique est avantageuse. Néanmoins, l'approche photogrammétrique, quoique précise et peu coûteuse, requiert un opérateur expérimenté et exige la disponibilité d'un bloc d'aérotriangulation de qualité et apte à produire une carte A-1 au 1:50 000. Le récepteur GPS de moins haute gamme peut, suivant le rapport coût et temps, être d'une grande utilité lorsque l'une des situations suivantes se présente :

- bloc d'aérotriangulation non-disponible;
- bloc d'aérotriangulation de qualité douteuse;
- opérateur expérimenté non-disponible;
- et aucun appareil de restitution n'est accessible.

Le récepteur GPS Magellan à l'avantage principal d'être portatif et accessible par n'importe quel spécialiste car il est simple d'usage et autonome. De plus, il peut servir de source de positionnement lors de l'intégration de données multisources (foresterie, hydrologie, environnement...) dans un environnement SIG utilisant l'imagerie satellitaire et une base topographique.

Il faut noter que l'influence de la précision des points d'appui pour le géocodage des images sera beaucoup plus marquée pour des capteurs à haute résolution spatiale comme le MEIS aéroporté. De plus, il est très important de mentionner que les erreurs de pointé qui ont été évaluées à 1/3 de pixel ont une influence sur la précision des ortho-images finales. Il faut donc mettre beaucoup d'attention lors de la lecture des coordonnées images des points de contrôle à l'écran. La distribution des points doit également être homogène tout en permettant de couvrir l'ensemble de la région pour diminuer les erreurs d'extrapolation. Dans un contexte de production, un minimum de 10 points a été nécessaire pour la correction d'une image SPOT-HRV pour conserver la précision de la carte au 1:50 000 [Savopol et Leclerc, 1991]. Finalement, on peut conclure qu'avec l'intermédiaire d'un SIG et de l'imagerie satellite SPOT-HRV, il est possible de produire et de mettre à jour des cartes topographiques au 1:50 000.

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Figure 1 - Scène entière d'une image SPOT-HRV panchromatique prise en juin 1987 de la région de Sherbrooke

On remarque la distribution de certains points employés soient comme points de contrôle ou comme points de vérification. Le cadre blanc représente la couverture d'un feuillet cartographique au 1:50 000.

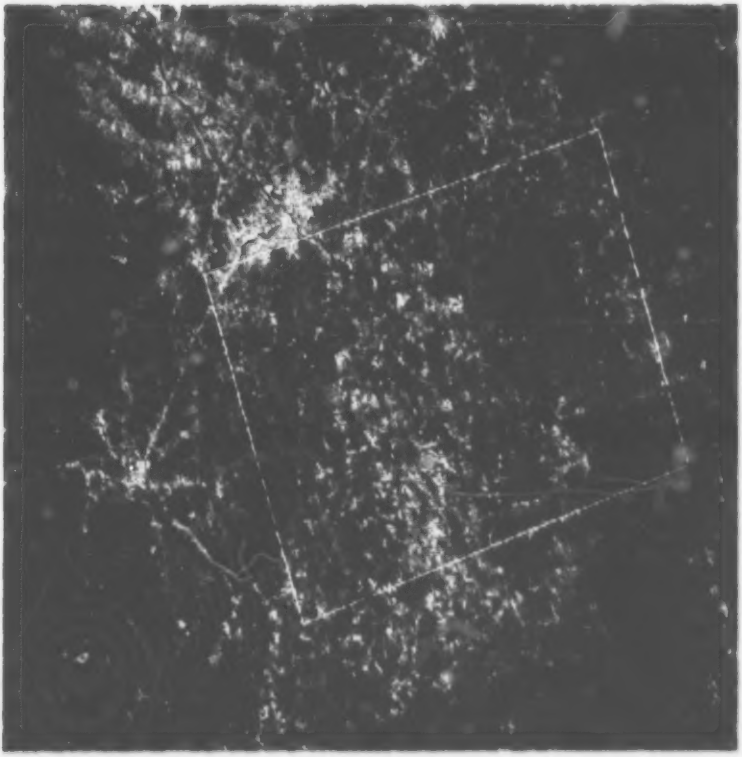

Figure 2 - Étapes menant à la collecte des stations GPS Magellan

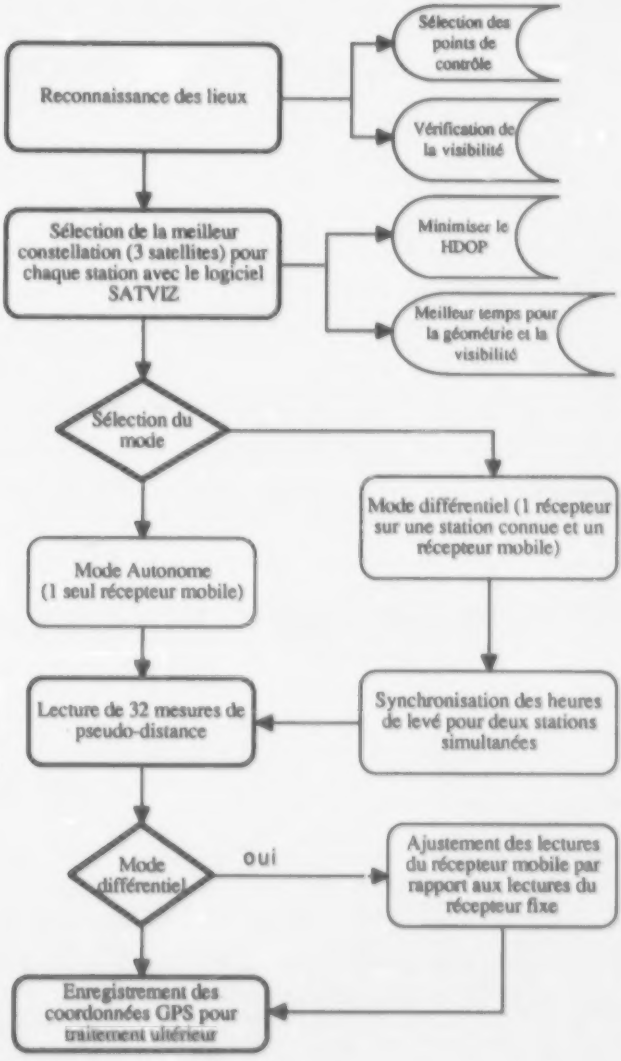

Tableau 1 - Comparaison entre les différentes sources de contrôle et les coordonnées GPS Ashtech

Type de contrôle		Nombre de stations	Écart-type (m)		Erreur planimétrique (m), (p=68%)
			X	Y	
Carte		30	19.0	16.8	25.1
Fichier d'aérotriangulation		30	2.0	2.6	3.2
GPS Magellan	Autonome	11	7.9	4.8	9.2
	Différentiel	11	4.5	3.8	5.8

Tableau 2 - Précision des ortho-images produites à partir de différentes sources de points de contrôle

Type de contrôle		EMQ (m) (p=68%)		Biais (m)		CMAS (m) (p=90%)
		X	Y	X	Y	
GPS précis Ashtech		3.5	5.9	1.1	0.5	10.2
Carte		3.5	10	-1.3	6.9	16.0
Fichier d'aérotriangulation		4.8	5.9	2.6	-0.9	11.5
GPS Magellan	Autonome	5.9	7.8	4.4	-0.6	14.8
	Différentiel	4.1	6.3	-2.9	0.2	11.3

Figure 3

Diagramme de distribution des erreurs CMAS des ortho-images en fonction des erreurs planimétriques des points d'appui

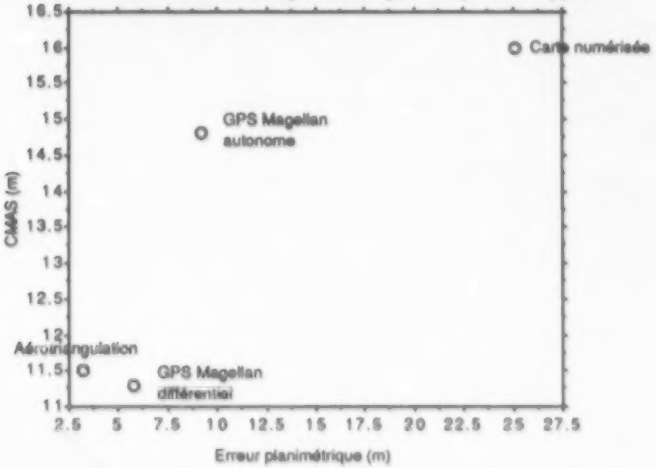

Tableau 3 - Estimation des temps et des coûts liés aux sources pour l'acquisition points de contrôle (31 stations - jeu de données de Sherbrooke)

Type de contrôle	Temps d'acquistion	Temps de traitement	Coûts estimatifs
GPS Ashtech	15 jours; équipe de 6 personnes	5 jours	$800 / station
GPS Magellan (mode différentiel)	3 jours; équipe de 3 personnes	2 jours	$115 / station
Photogrammétrique	1 journée; un opérateur spécialisé	3 heures	$15 / station
Cartographique	1/2 journée; un opérateur	3 heures	$18 / station

HIGH ACCURACY C/A CODE GPS TECHNOLOGY FOR GIS APPLICATIONS

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SUMMARY

The impact of the Global Positioning System (GPS) on the surveying and mapping community has already become significant, while its use in Geographic Information Systems (GIS) is just beginning to be realized. GPS offers tremendous advantages in the positioning of geographic data. The system will provide all-weather, 24 hour world-wide satellite coverage when it becomes operational in late 1993. This means that theoretically, the same positioning accuracy is acheivable anywhere on the Earth at any time of day, which makes GPS georeferencing a global solution to spatial information management.

In mid-1991, a new type of Coarse/Acquisition (C/A) code GPS receiver was unveiled by NovAtel Communications Ltd. (Fenton et al, 1991). This receiver is categorized as a low-cost receiver targetted to the OEM market. Due to the availability of both the raw pseudorange and carrier phase measurements, the NovAtel GPSCard™ can be used for a wide variety of positioning tasks, ie. ranging from instantaneous single point solutions to precise static differential surveys. The receiver is mounted on a card which can be housed in a portable PC for easy transport (Fenton et al, 1991).

One of the many unique characteristics of this receiver is a 10 cm C/A pseudorange measurement level, i.e., one order of magnitude better than any other C/A code receiver technology currently on the market. This is a critical threshold since it represents approximately one half wavelength at the L1 frequency (~ 19 cm), i.e., the accuracy level required to solve the carrier phase ambiguity instantaneously and fully exploit the millimetre accuracy level provided by carrier phase measurements. The implication is that centimetre level accuracies will be achievable in real-time when two GPS receivers are operated in differential mode with an auxiliary communication system. This opens the door to numerous possibilties for real-time georeferencing applications.

TECHNOLOGIE DU CODE GPS C/A DE GRANDE PRÉCISION POUR LES APPLICATIONS DE SIG

RÉSUMÉ

L'incidence du Système de positionnement global (GPS) en arpentage et en cartographie est déjà importante alors que son utilisation dans les systèmes d'information géographique (SIG) débute à peine. Le GPS présente des avantages considérables pour le positionnement de données géographiques. Les satellites de ce système offriront par tout temps une couverture mondiale ininterrompue lorsqu'il deviendra opérationnel à la fin de 1993. Cela signifie théoriquement qu'une même précision de positionnement est possible partout sur la Terre à toute heure du jour, ce qui fait du repérage géographique au moyen du GPS une solution globale de gestion de l'information spatiale.

Vers le milieu de 1991, un nouveau type de récepteur du code C/A (coarse acquisition) du GPS a été lancé par la NovAtel Communication Ltd. (Fenton et coll., 1991). Ce récepteur entre dans la catégorie des récepteurs peux coûteux destinés au marché OEM. En raison de la disponibilité de mesures de pseudo distances et de phase porteuse, le NovAtel GPSCard^{md} peut être utilisé pour une gamme étendue de tâches de positionnement, depuis des mesures de distance d'après des solutions instantanées pour des points individuels à des levés différentiels statiques précis. Le récepteur est monté sur une carte qui peut être logée dans un OP portatif afin d'en faciliter le transport (Fenton et coll., 1991).

L'une des nombreuses caractéristiques uniques de ce récepteur est la mesure de pseudo distances avec le C/A à 10 cm près, c'est-à-dire avec une précision supérieure par un ordre de grandeur à celle des récepteurs du code C/A actuellement disponibles. Il s'agit d'un seuil critique puisqu'il correspond approximativement à la moitié de la longueur d'onde à la fréquence L1 (= 19 cm), c'est-à-dire à la précision nécessaire pour lever instantanément l'ambiguité de la phase porteuse pour ainsi permettre d'exploiter pleinement la précision millimétrique que permettent les mesures à l'aide de la phase porteuse. Il en découle qu'il est possible d'obtenir en temps réel des précisions de l'ordre du centimètre lorsque deux récepteurs GPS sont exploités en mode différentiel avec un système de communication auxiliaire. Cela offre de nombreuses possibilités en rapport avec des applications de repérage géographique en temps réel.

In order to assess the quality of the carrier phase measurements as well the pseudorange accuracy in typical operational conditions, land semikinematic tests were conducted with the NovAtel GPS Card™ by The University of Calgary on the Kananaskis Test Network. Antennas were mounted on choke rings for both the monitor and vehicle antennas for multipath reduction. Semikinematic data were post-processed using The University of Calgary's SEMIKIN program (Cannon,1990a) and results given in Table 1 are a summary of those reported in Cannon and Lachapelle (1992). Accuracies of less than 5 cm are generally achieved when positions derived from NovAtel data are compared to the control coordinates. These results are compatible with those achieved with typical 'geodetic' GPS receivers, which generally cost between $30,000 and $40,000 (ibid).

Table 1: Results of Semikinematic Survey

Station	Latitude	Accuracy: Longitude	Height
16AW		Monitor station	
16AE	Ambiguity resolution: static initialization with remote unit		
16BW	-4.0 cm	1.6 cm	-0.1 cm
17W	3.1	0.0	-3.3
17BE	0.6	1.9	1.4
17E	1.9	-6.4	0.8
16AE	-1.2	-5.4	-3.6

A second analysis of the data was done to assess the accuracy of the pseudorange data. Differential positions were determined using the pseudorange data and results are reported in Table 2. As can be seen, for the pseudorange only case, differential positons have an root mean square (RMS) of less than 1 metre. Accuracies of 5-10 m can usually be expected with other C/A code receivers (e.g. Cannon,1987). When carrier smoothing is applied to the pseudorange observations (Hatch,1982), accuracies improve to about the 50 cm level. It has been shown that with other C/A code receivers, accuracies at the 1-3 m level can be expected when carrier smoothing is implemented, see Lachapelle et al. (1987a) for example. Further testing is currently underway to fully exploit this pseudorange accuracy for 'on the fly' carrier phase ambiguity resolution.

The availability of a positioning capability with the accuracies shown above can serve many applications in the GIS field. Some examples are the establishment of property boundaries and the georeferencing of underground utilities. Clearly, the more accurately these features can be positioned, the higher the integrity of the database to which these data are entered. The location of underground pipeline crossings is another example which requires accurate positioning. Since high accuracies have also been demonstrated in a kinematic environment using the

NovAtel GPS Card™, the efficiency of data gathering will improve substantially. With the advent of stereo video imagery and the establishment of data transmission over cellular networks (i.e. 5-10 kbps), accurate real-time georeferencing will become a reality. A further discussion on the impact of GPS technology on GIS can be found in Lachapelle et al. (1987b) and Cannon (1990b).

Table 2: Single Difference Pseudorange and Carrier Phase Smoothed Pseudorange Positioning

Coordinates	Pseudorange Only			Phase Smoothed Pseudorange		
	Δ_{mean}	Δ_{max}	RMS	Δ_{mean}	Δ_{max}	RMS
Latitude	-0.02 m	3.45 m	0.82 m	-0.14 m	-2.54 m	0.50 m
Longitude	0.12	2.42	0.56	0.01	-1.26	0.28
Height	0.00	-5.49	0.99	-0.27	-3.88	0.66

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Think Global.....Act Local

With GIS in Egypt

BY

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Abstract

This paper's main objective is to describe the early experience of an established GIS Water Resource Management Project in Egypt.

The project is a joint project undertaken by the Water Research Center (WRC), Ministry of Public Works and Water Resources, Egypt; in collaboration with The International Development Center (IDRC), Ottawa, and The Survey, Mapping and Remote Sensing Sector (SMRSS), Energy, Mines and Resources Canada.

This paper depects the project's aim and objectives, its technical concept and implementation phases; as well as problems and queries raised locally concerning GIS applicability and suitablility to Egyptian conditions.

The introduction of GIS technology in developing countries forms a challange, as it is relatively a new field of study locally; which is not fully comprehended. Thus many questions arise.

Perhaps the most outstanding question raised in this case is whether or not this technology will thrive and progress to be utilized successfully in Egypt or not ?

Since the project is only one year old, expectations and judgments in this concern are rather premature.

Penser globalement ... agir localement
Les SIG et l'Égypte

RÉSUMÉ

Le principal objet du présent article est de décrire les débuts de l'établissement d'un projet de gestion par SIG des ressources hydriques en Égypte.

Ce projet conjoint est entrepris par le Centre des recherches sur les eaux du ministère des travaux publics et des ressources en eaux d'Égypte en collaboration avec le Centre de recherches pour le développement international (CRDI), Ottawa et le Secteur des levés, de la cartographie et de la télédétection, d'Énergie, Mines et Ressources Canada.

L'article présente les objectifs du projet, son concept technique et les phases de sa mise en oeuvre ainsi que les problèmes et questions soulevés localement au sujet de capacités d'applications des SIG et de leur utilité en fonction des conditions en Égypte.

L'introduction de la technologie des SIG dans les pays en voie de développement constitue un défi, parce qu'il s'agit là d'un domaine d'étude relativement nouveau, que l'on ne connaît pas encore complètement. De nombreuses questions sont donc soulevées.

La question la plus importante dans ce cas est peut-être de savoir si cette technologie progressera et pourra être utilisée avec succès en Égypte ou pas?

Puisque ce projet n'a qu'un an, il serait prématuré de vouloir répondre à cette question.

I. Background:

Egypt's agricultural sector is unique, in that over 95% of its production is derived from irrigated land and its irrigation waters originate totally outside its borders. Our rapidly increasing population is placing severe demands on Egypt's limited supply of agricultural land (7.4 million acres at 1990). Over 50,000 acres are lost to urbanization annually. The more intensive farming practices needed to meet the nutritional demands of the population have led to increased water logging and soil salinity and have necessitated extensive agricultural development of formerly desert land.
As a result, the Egyptian Ministry of Public Works and Water Resources has been tasked with the formulation of plans for the intensive development of all potential sources of water and the optimum effective utilization of all immediately available water.
One of the programs designed to help achieve these goals; is the GIS Water Resource Management Project.

The GIS Water Resources Management Project in Egypt joint undertaking by the Water Research Center (WRI), Ministry of Public Works and Water Resources, the International Development Center (IDRC) in Ottawa and the Surveys, Mapping and Remote Sensing Sector (SMRSS), Energy, Mines and Resources Canada. The objective of the project is to establish a Geographic Information System in the Survey Research Institute (SRI) of the Water Research Center to manage the water related issues in the irrigation system in a pilot area of the Giza Governorate. Although the scope of the project is limited to pilot area it is expected that the solutions obtained from this project will be extended to other areas after the completion of this project.

The project commenced December 1990, funded by IDRC. But due to the Gulf war the real activity started in March 1991.

II. Project Objectives:

The overall objective of the project is to develop a prototype Geographic Information System (GIS) for the storage, manipulation and analysis of data that will be applied for short and long-term management of the water resource in Egypt. The project will make full use of the GIS technology, in Egypt. The project will make full use of

the GIS technology, in conjunction with the exploitation of spatial hydrological models. The specific objectives of the project are as follows:

- to collect and review state-of-the -art literature and research concerning GIS and computer modelling procedures for water resources management;
- to analyze the existing water resource problems of water logging, salinity, seepage and silting;
- to select, modify and adapt existing spatial hydrological models and sub-models for water resources management to address the above water resources problems in a GIS environment;
- to collect the thematic data required by the Geographic Information System (soil types, hydrogelogic data, topographic data, etc.) in a pilot area (< 10 km2); and to develop a corporate database;
- to develop the applications software and procedures for exploitation of the database in a GIS environment; to select and acquire an optimum hardware configuration to support the database, software, and models; and to implement the Geographic Information System;
- to apply and monitor a hypothetical spatial modeling scenario and to evaluate the performance of the Geographic Information System on one of the issues specified under Task 2 of Section 7; and
- to ascertain the future potential of the Geographic Information System in the context of regional management of the water resource.

III. Anticipated Results:

It is anticipated that, upon completion of the project, the following results will be achieved:

- A prototype hardware and software system that will facilitate the modelling of complex problems related to water resources development and management. More specifically, the proposed project will generate a series of tools for evaluating the potential and effectiveness of various water management alternatives to help alleviate problems such as water logging, salinity, and reduced crop production.
- State-of-the-art GIS modelling procedures that will facilitate the integration of spatial and point data in the solution to various water resources problems.

- A comprehensive database of a pilot area, comprising digital areal (topography, soil types and properties, vegetation cover, etc.), line (drainage and irrigation networks, etc.), and point (flow rate, pumping rates, etc.) data.
- The first step towards a regional Geographic Information System that could be used for investigating various water management and development options at a scale of the entire Nile Delta.
- Results of an analysis pertaining to the success of the proposed GIS in the context of regional scale studies.
- Development of expertise by the Egyptians in the development and use of a GIS for water related studies.
- Publication of the results in well-known scientific Journals (e.g Journal of Hydrology, ASCE Journal of Water Planning and Management, etc.), presentations at various conferences and news releases or articles in Arabic in local publications.
- The project will provide EMR with experience in hydrology modelling for GIS applications in Canada. The model will be installed in the National GIS Technology Center of EMR for application development.

IV. Technical Concept:

To be specific GISWRM is developed to help answering where, when and how much water to deliver to address the main two water related issues:

1. Minimize water logging problems and salinity build-up.
2. Maximize Crop productivity due to optimum water use.

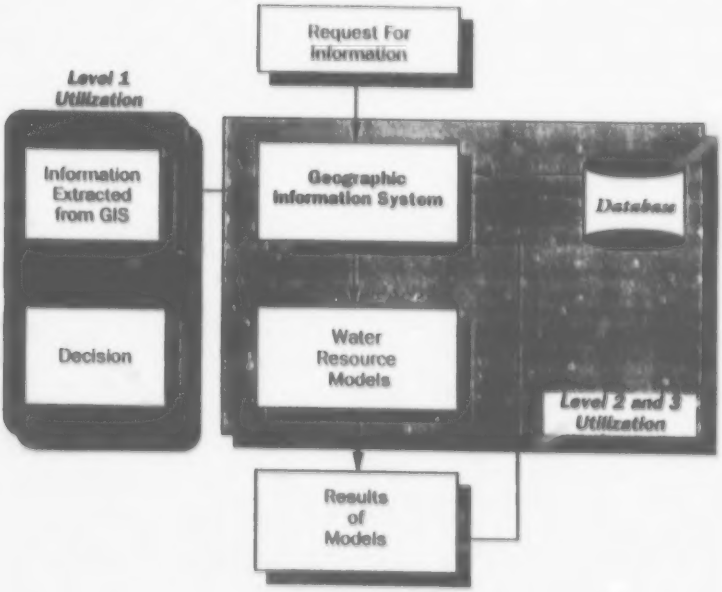
The Technical Concept is to start by developing a data-base for the pilot area, then using it with GIS to give the ability to manage, analyze, manipulate,and display geographically referenced data.
On the other hand integrate GIS with one or more hydrological WR model as a very powerful analysis tool.

By linking WR models with GIS, this will result the ability to:

- Manipulate input data
- Generate input data files
- Display, Manipulate output results
- Facilitate analysis of scenarios
- To calibrate models

Concept

GIS — Water Resources Model Integration



V. Implementation Phases:

Task 1: Literature Review

An extensive literature search will be conducted to collect and revise state-of-the-art work in the field of GIS and computer modelling procedures for water resources management.

Task 2: Identification of key water related issues

The GIS-hydrologic model system to be developed should be robust and flexible enough so that, with minor modifications, it will handle water resource problems other than those for which the System was originally designed.

Task 3: Selection of suitable water resources models:

Under this task, water resources models that meet the needs and requirements highlighted in Task 2 will be selected. Normally, no single model will address all the issues, so that more than one hydrological model will probably be needed.

Task 4: Data collection:

The objective of this task is to ensure that all the thematic information required for the project is collected and organized. The data for this task will follow directly from task 2, and task 3.

Task 5: Selection of GIS software and hardware configuration and DBMS.

The selection of the basic GIS software and Database Management System (DBMS) will be done based on technical as well as practical considerations.

Task 6: Develop the corporate database:

A GIS database will be developed for the pilot area. All the data collected in Task 4 will need to be converted to a standard digital format compatible with the selected GIS software.

Task 7: Implementation of the Geographic Information System and DsMS:

In this task, all the elements developed in Task 3, 5 and 6 will be implemented in the hardware system, and procedures to access and manipulate input data and output results will be established.

Task 8: Application of GIS to a water management scheme:

The application will involve the following steps:

1. A water resources problem will be selected, and a management scenario will be created.
2. The scenario will be fed into the GIS for evaluating the system's performance in producing the required outputs & calibration of the hydrological model.
3. The performance of the system will be further evaluated by simulating variations of the hypothetical water resources scenario.
4. Remedial measures to correct deficiencies and errors in the GIS will be proposed and implemented.

Task 9: Evaluation of GIS for regional planning:

The objective here is to investigate the potential and propose mechanisms to use the Geographic Information System in the context of regional water resources planning.

IV. Think Global, Act Local:

GIS (Geographic Information Systems) technology is a widely misunderstood technology. Nowhere is that misunderstanding greater then in developing countries. Because exposure to the technology is frequently limited to what can be gleaned from dated technical journals or an occasional traveling salesmen, individuals in developing nations charged with implementing GIS technology frequently overestimate their organization's readiness to take on the technology and underestimate the time and effort required of a successful and sustainable implementation.

Eventually most developing nations turn to international consultants (experts) for advice and help with implementation. Unfortunately, GIS consultants frequently have little prior experience with the environment into which

they are asked to introduce the technology. As a result, they, too, overestimate organizational readiness and underestimate the time and effort required for implementation.

What then must developing nations and their GIS consultants know to effect a successful implementation ? Here are some tips based on observation of GIS/WRM as well as a number of GIS projects in Egypt.

What It Is - What It Is Not

First and foremost GIS technology is an information management technology. It is not a surveying and mapping technology. Its successful application requires an understanding of the principles and concepts of mapping and to a lesser degree surveying. *More important though is an understanding of the application for which it is to be used.*

Practically, a geographic information system is *nothing more than a set of software tools* designed for managing, analyzing and displaying the contents of a database containing data which has been geocoded; that is, assigned unique identifiers relating selected elements in the database to their physical location on the surface of the earth or in space.

Generally, the more expensive the geographic information system, the more complete and complex the toolkit. The more complete and complex the toolkit, the more difficult it will be to learn and master. Top of the line GIS software is not for novices unless they have the time and money to become experts. *Not every organization needs a top of the line geographic information system.* For most it makes more sense to start with a simple system and develop staff expertise slowly and deliberately.

Personnel and Training

The successful implementation of GIS technology depends first and foremost on the availability of a sufficient number of individuals interested in learning the technology and having a suitable educational background and practical experience with related technologies.

As few developing countries can meet this condition, the international experts chosen to help introduce GIS technology to a developing country must be equipped to

provide both long and short-term GIS training as well as basic and advanced computer training for the personnel of the implementing agency.

In assessing the qualifications of GIS consultants, implementing agencies should pay particularly close attention to the training programs proposed. Here are some items to consider.

- *Does the program provide off-shore academic training for a few of the most promising trainees?* The long-range sustainability of national programs will require the availability of a few individuals with advanced academic training. Be sure you understand how many individuals will be trained, in what subjects and for how long. More important, understand why they are being trained, and how they will be utilized when their training is finished. Off-shore academic training is expensive. Be sure you can get full value from the training of all returning trainees-otherwise don't send them.

- *Has provision been made for training trainers?* The implementation of GIS technology is a long term endeavors. Personnel initially assigned to the project will move on. New organizational entities will join the project. Continued success requires that you develop the in-house capability to train additional personnel as the need arises. The sooner you do this the better off you will be. Don't skimp in this area.

- *Are the training plan's objectives clearly spelled out?* Are they realistic-given the current level of expertise of the staff to be trained? Be honest with yourself. Don't let personal or organizational pride cloud your judgement. Accept the fact that you are far more likely to overestimate the capability of your current staff than underestimate it.

- *Are the costs reasonable? Affordable?* Good training takes time. It is not cheap. On the other hand, you cannot afford to spend your entire budget training personnel. Training is after all a means to an end-implementation of a functioning geographic information system. Most new users of GIS technology grossly underestimate the time required to achieve even a modest level of

proficiency. Ten to fifteen percent of your budget is not too much to spend on training. The larger the budget, the smaller should be the percent.

User Requirements

The best trained staff cannot successfully implement a geographic system without a clear definition of the tasks for which management intends to use the system. An experienced GIS consultant will have helped numerous organizations define their requirements. He will undoubtedly have all sorts of questionnaires and forms available for assisting with this critical and demanding task. Unfortunately, many, if not all of them, will be of little value in developing countries. Why? *Management and user unfamiliarity with information systems technology in general and GIS technology in particular.*

Before he can help the implementing organization define its requirements, the international consultant will find that he must spend considerable time educating management and potential users in the rudiments of GIS technology and the importance of their participation in the requirements definition process. Based on our experience in Egypt, international consultants selected to assist developing countries implement GIS technology should be prepared to answer the following types of questions:

- *Show-me.* Because most individuals tasked to participate in the requirements analysis will be unfamiliar with GIS technology, consultants should be prepared to demonstrate a working GIS. The ready availability of PC-base geographic information systems makes this a practical requirement. This demonstration system need not be complex. It need not even cover the specific application of the implementing agency, although it would be more effective if it did. It should be complete enough to enable potential users to begin to imagine how they and their organization might profit from the introduction of GIS technology.

- *What-if.* GIS technology has introduced a new variable to information processing and management. That variable is location. Its presence makes possible the formulation of What-if questions relating to the placement and movement of physical objects. Consultants should be prepared to clearly explain and demonstrate this capability to potential users before

asking them to define their requirements.

- *Spatial information.* Although it may seem obvious to those familiar with GIS technology, the inherent capability of all geographic information systems to respond to routine inquires such as: How many are within __? Find all the __at? How many are near __? What has changed since __? How far from __is__? Is frequently not understood or greeted with skepticism. Even brief exposure to practical working applications will go a long way toward helping those unfamiliar with GIS technology formulate their own user requirements.

Information Is Power

GIS technology offers the potential for revolutionizing the way organizations and people interact and conduct business. To realize its benefits, individuals and organizations must be open to change - change in the way they collect, process, handle and disseminate information. They must be open to rethinking the purpose and structure of their organizations. GIS technology is not a tool for doing business as usual. For innovative, forwarding - looking organizations capable of mastering the technology, the potential for betterment is virtually limitless. For organizations and managements not open to change, GIS technology is life threatening.

Anyone who has eve worked in a bureaucracy knows that control of information is the ultimate source of power. Government agencies in developing countries are highly bureaucratized and highly centralized. Any system that offers to change the traditional approach to information collection, management and dissemination will immediately be seen as a threat to the entrenched power holders.

As a result, consultants tasked with the implementation of geographic information systems in developing countries frequently find their access to information barred or at least made very difficult and time consuming. Those who offer their services to assist a developing country with a GIS implementation must be prepared to deal with resistance to change, information blackouts and many false starts. The task of introducing GIS technology to a developing nation is not one for those easily frustrated or short on patience.

Conversely, implementing organizations must recognize that these bureaucratic delays cost money. As they cannot expect their consultants to work for nothing, they must be prepared to run interference for their consultants by aggressively

attacking organizational barriers and inertia. If they are not prepared to do so, they should abandon the idea of implementing a geographic information system.

Necessity or Luxury

While by no means a panacea for all that ails a developing country - as some may claim - prudently implemented, GIS technology does offer a forward-thinking developing nation the opportunity to better manage its human and material resources for the good of its progeny.

A number of demonstration projects in Egypt have just started to conclusively show that the wholesale implementation of GIS technology could material improve the country's ability to manage its land, water and agriculture resources. When viewed from a purely technically perspective, it is safe to say that the coordinated application of GIS technology should proceed forthwith throughout a number of Egyptian ministries. There is little doubt in the minds of those associated with these demonstration projects that GIS technology is now a technical necessity for Egypt.

Unfortunately, the wholesale implementation of GIS technology will cost millions, if not billions, of Egyptian pounds, pounds which are not now available in the government's budget and which are not likely to be available in the foreseeable future. From a political and financial perspective, GIS technology is a luxury and is likely to remain a luxury for years,m if not decades, to come. What then is Egypt to do?

For the present time Egypt must continue to rely on international development organizations such as IDRC,GTZ and USAID to fund the development of its GIS systems. Until now these organizations have only been willing to fund small demonstration or pilot projects. If GIS technology is to be implemented on a large scale anytime soon within Egypt, a way must be found to convince these and other international development organizations that it is in their own, as well as in Egypt's, best interest that GIS technology move from its current position as a nice to have luxury to a cannot do without tool for national development.

APPLIED RESEARCH IN GEOGRAPHIC INFORMATION SYSTEMS IN DEVELOPING COUNTRIES: IDRC'S EXPERIENCE

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Abstract

In 1987, the International Development Research Centre (IDRC) supported its first research project on the utilization of Geographic Information Systems (GIS) technology dealing with the Caribbean Coastal Zone in Colombia. Since then, eleven other projects have been developed in Africa, Asia, and Latin America, covering diverse subjects such as soil fertility and erosion (Nepal); flooding (China); socio-economic changes (India); watershed basin hydrogeology (Ivory Coast); municipal planning (Costa Rica); local-level mapping (Nigeria); water management (Egypt); agricultural land improvement (Morocco); coastal area management and planning (the Philippines); and natural resources conservation (Tunisia). In spite of the wide range of themes covered, these projects are aimed at assessing a combination of natural resources and socio-economic factors. The variety and nature of the themes studied, as well as the geographic distribution of the projects, has allowed certain conclusions to be drawn on the potential utilization of GIS technology as a decision-support tool in developing countries.

RECHERCHE APPLIQUEE EN SYSTEMES D'INFORMATION A REFERENCE SPATIALE DANS LES PAYS EN VOIE DE DEVELOPPEMENT: L'EXPERIENCE DU CRDI

Résumé

En 1987, le Centre de recherches pour le développement international (CRDI) a développé son premier projet de recherche sur l'utilisation des systèmes d'information à référence spatiale (SIRS). Il s'agissait de l'étude de la zone côtière dans les Caraïbes (Colombie). Depuis, onze autres projets ont suivi en Afrique, en Amérique Latine et en Asie traitant de sujets aussi variés que la fertilité et l'érosion des sols (Népal); les inondations (Chine); les changements socio-économiques (Inde); l'hydrogéologie d'un bassin versant (Côte d'Ivoire); la gestion municipale (Costa Rica); la cartographie locale (Nigéria); la gestion de l'eau (Egypte); la mise en valeur agricole (Maroc); la planification et la gestion des zones côtières (Philippines); et la dégradation des ressources naturelles (Tunisie). Bien que traitant de sujets variés, ces projets sont axés sur l'étude combinée des ressources naturelles et des phénomènes socio-économiques. La variété et la nature des thèmes abordés ainsi que la distribution géographique de ces projets nous ont permis de tirer certaines conclusions sur l'utilisation potentielle de la technologie des SIRS comme outil d'aide à la prise de décision dans les pays en voie de développement.

INTRODUCTION

The International Development Research Centre (IDRC) is a public corporation established by the Parliament of Canada in 1970 to stimulate and support scientific and technical research in developing countries. IDRC is somewhat unique among development aid agencies because it has stressed information sciences from the outset, in addition to its support for programs in areas such as agriculture, food and nutrition sciences; health sciences; and social sciences (Stone, 1985).

With the continuing evolution of information technologies, Geographic Information Systems (GIS), which can assist in the management, analysis, and presentation of information in a suitable form for policy- and decision-making, have proven to be of special importance in environmental and natural resource information management in developing countries. GIS is also an area in which Canada has demonstrated technical leadership, both from the technology development and implementation points of view.

Since the development of microcomputer-based GIS in 1980s, IDRC recognized the potential offered by these techniques in meeting the needs of developing countries for mapped information, and began to support applied research involving their use in several sectors (including forestry, water and soil resources, agriculture and fisheries). In the area of new information techniques, support is provided by the Information Tools and Methods group (which includes the Geomatics Program) of the Information Sciences Division for activities such as technology assessment, selection, evaluation, and testing; feasibility studies and technology demonstrations; pilot projects and experiments; technology introduction and transfer; technology adaptation and development; education and training; and exchanges of experience.

Projects dealing with the application of GIS technology to provide up-to-date information on natural resources have been funded in eleven developing countries (China, Columbia, Costa Rica, India, Ivory Coast, Egypt, Morocco, Nepal, Nigeria, the Philippines, and Tunisia). These projects represent different experiences in technology transfer, and provide an opportunity to test the feasibility of applying GIS for the production of thematic information essential to development. Many of these IDRC-funded projects have dealt with the assessment and monitoring of land and water resources.

SUMMARY OF SELECTED IDRC-FUNDED GIS PROJECTS

The following provides a brief description of GIS projects supported by IDRC. Some of these projects are executed in cooperation with a Canadian research institution, others entirely by developing-country institutions. IDRC also promotes the joint-execution of research projects by institutions of different developing countries.

GIS ON THE CARIBBEAN COASTAL ZONE, COLOMBIA, 1987-1989

This project was developed and carried out by the Colombian Centre for Oceanographic and Hydrological Research (CIOH).

The purpose of the project was to enable CIOH to establish a microcomputer-based GIS aimed at supporting the collection, management and analysis of spatially-referenced information about the Caribbean Coastal zone of Colombia, including natural resources, land-cover, socio-

economic, legal and administrative ...ion for two test sites. The general objective was to strengthen the capacity of an info... ...entre on the Caribbean Coastal zone of Colombia by providing a tool to adequately store and package the available information in order to help establish appropriate criteria for the administration and the development of this region.

Two sites were selected to test GIS techniques. The first was a well-studied, well-developed area of Cartagena with an area of 244 000 hectares covered by fourteen sheets of a 1:25 000 scale topographic map; and the second was a less-documented and less-developed area of Morrosquillo with an area of 360 000 hectares covered by twenty sheets of a 1:25 000 scale topographic map. The two areas presented sufficiently varied conditions to provide enough variables and issues to test the effectiveness and efficiency of GIS techniques under different conditions of development.

The project achieved a successful transfer of Canadian technology to CIOH. It helped the development of GIS capabilities at CIOH, and demonstrated the appropriateness of these techniques for coastal zone management. Several Colombian institutions requested CIOH to provide them with information generated by the system for their own sectoral use. Among the project recommendations were: integration of all existing information on the coastal zone in a GIS; extension of the study area to the whole Caribbean coast; maintenance and update of the system; and training of personnel in GIS software use and GIS application development.

SOIL FERTILITY AND EROSION, NEPAL, 1988-1991

This project was developed and carried out by the Integrated Survey Section (ISS) of the Topographical Survey Branch of the Government of Nepal, with the collaboration of the Department of Soil Science at the University of British Columbia.

In the hills of Nepal, where population pressures are greatest, soil degradation, erosion, and sedimentation are serious problems. The three processes are interlinked and a better understanding and quantification of them can certainly be helpful in developing more productive and sustainable forestry and farming systems.

The overall objective of the project was to identify the causes and nature of soil erosion, soil fertility decline and sediment transport in small watersheds in the hills of Nepal. This was done by integrating biophysical resource and land-use information based on aerial photographs using a microcomputer-based GIS to develop possible solutions to improve biomass production on a sustainable basis.

The selected test site for this study is the Jhikhu Khola Watershed, 40 kilometres north-east of Kathmandu. It is a typical Middle-Mountain watershed with clear evidence of soil erosion due to natural causes, overgrazing and deforestation. About 20% of the watershed consists of red soils which are widespread in the Middle Mountains and which have proven to be the most difficult to revegetate once degraded. An afforestation program is ongoing in the watershed and an all-weather road provides good access to it.

The project established that the GIS had the capacity to fit together the complex components of the study. It provided a better understanding of the processes and interactions involved, and ultimately proved useful in providing better solutions for natural resource management. However, the huge amount of reliable data needed for a valuable GIS limits the area that can be covered. An attempt was made by the project to use national figures to derive

current and future food, fuel and fodder sufficiency by district in Nepal, but unfortunately national statistics were too poor to use in a GIS, and this consequently limited the effectiveness of the GIS for this application.

GIS - DONGTING LAKE, CHINA, 1988-1991

Several Chinese research institutions were involved in this project, the principal being the Laboratory of Resources and Environment Information Systems (LREIS), which is the leader in GIS technologies in China.

This project was aimed at developing a GIS-based approach to produce cartographic information for flood damage control and management. A computerized geographic database was designed and established for the Dongting Lake Region in China, a key region suffering from major flooding problems. The GIS database was used to dynamically display environmental changes and to estimate losses in case of flooding, as well as for the selection of flood gates and the allocation/distribution of disaster relief materials. In addition to the GIS component, the use of different remote-sensing tools was investigated to monitor environmental changes in the region and to keep the geographic database up-to-date. The project included an important component in GIS technology transfer from Beijing to a provincial Chinese research centre, which is expected to provide planning information to local decision-makers. In addition, a GIS atlas of the Dongting Lake region has been published, and an international seminar was held to share and disseminate the GIS approach to individuals of other flood-sensitive regions in China and in several other countries in Asia.

The study area is the Dongting Lake region in Hunan Province which consists of a vast flood and alluvial plain surrounded by hills located in the middle reach of the Yangtze River. It covers about 20 counties and 15 state farms. The total area of the region is about 32 000 km^2, of which 15 000 km^2 are dyke-surrounded areas, 2 700 km^2 are natural lakes and 1 000 km^2 are flood channels. The total population in the region is close to seven million. Flooding, waterlogging, silting and disease continuously threaten the population (Lu *et al.*, 1990). Dongting Lake is the second largest fresh water lake in China.

The Hunan Remote Sensing Centre, where the GIS-based flood damage evaluation system has been installed, will enable local planners of the Dongting Lake Region to access timely and well-packaged geographic information for flood damage control and management. Dissemination activities are expected to introduce the GIS technology and products to scientists and planners of other flood-sensitive regions of China and neighbouring countries.

In addition to the development of several databases, analytical and operating models in a GIS environment, the project contributed to a better knowledge of the inundation process in the Dongting Lake region, and achieved a successful transfer of technology from Beijing to the local staff in the Changsha Regional Branch of the National Remote Sensing Centre. The project generated considerable interest at the decision-making level as well as the grass-roots level.

BIHAR: AN EVALUATION OF CHANGE, INDIA, 1988-1991

This project was developed and carried out by Kirori Mal College to investigate computer-assisted cartography and demonstrate the relevance of digital mapping techniques for sub-national planning. Kirori Mal College is a constituent college of Delhi University, and its

Department of Geography offers Bachelor of Arts degrees with Honours in Geography. It is one of very few Geography Departments in India experimenting with microcomputer-assisted mapping techniques.

The overall purpose of this project was aimed at demonstrating the suitability of computer-assisted cartography in mapping large volumes of data for planning at the sub-national level and at creating a comprehensive GIS for the State of Bihar to fulfil the mapping requirements of the Centre for Policy Research (CPR) and the Planning Commission (PC) for the purpose of evaluating socio-economic change in Bihar.

Bihar, with a population of over 75 million and an area of 174 000 km^2, is a State endowed with extensive, fertile agricultural land and rich mineral deposits. Bihar has lagged behind the rest of India despite receiving massive assistance from the Government through six successive five-year plans. To better understand the causes of this lag, and thereby to improve the planning process, the PC of India has retained the CPR to investigate the effect of successive plans on Bihar, and the CPR had requested Kirori Mal College to undertake the experimentation related to the use of new mapping techniques to handle and process geographical data.

As a result, the project has produced a comprehensive digital database on Bihar State, that is to be made available to users. The development atlas of Bihar, which is the first publicly available collection of maps produced by GIS and microcomputers in India, is being printed, and it will thus serve as a tangible example of the appropriateness of these computer-mapping techniques. Kirori Mal College students have played an active role in this project and have "learned by doing".

CATCHMENT AREA ON THE MARAHOUE RIVER, IVORY COAST, 1989-1992

This project was developed by the Université nationale de la Côte d'Ivoire in collaboration with the Centre d'applications et de recherches en télédétection (CARTEL) of the Université de Sherbrooke.

The overall objective of the project was to evaluate the water resources of discontinuous aquifers of a typical Sahelian hydrological basin, in order to better manage the resource. This evaluation is based on hydrological and geophysical data obtained in the field and from the analysis of satellite surveys using a GIS. When applied, the outputs of the project are expected to enhance the duration of water engineering works and improve chances for success of well-drilling.

The test area is a portion of the Marahoué watershed basin located in a sub-Sahelian climatic zone (1 250 - 750 mm. rainfall per annum), in Côte d'Ivoire. The watershed covers an area of 12 500 km^2 between 7°40' and 9°30' North latitude and 6° and 7° West longitude. Its outlet is located at the junction of the Yanani and Marahoué Rivers, not far from Séguéla. A set of remote-sensing data obtained during the dry season was used for geological mapping, and particularly for the identification of lineaments and the determination of their principal characteristics (Biémi *et al.*, 1991). All field data and attributes including topographical, geomorphological, hydro-meteorological, hydro-geological, hydrological, geological, geophysical as well as socio-economic data have been digitized, and are handled by a GIS.

Partial conclusions of the project have been drawn regarding the relationship between the main lineament directions detected on remote-sensing images and the location of wells presently

in use and their flow rates. In addition, a new diagram for the control of well-drilling operations and the prediction of wells' characteristics in term of productivity and perenniality in fissured bedrocks has been designed.

GIS FOR SMALL MUNICIPALITIES, COSTA RICA, 1989-1992

This project was developed by the School of Geographic Sciences of the National University of Costa Rica, with the active participation of the National Institute for Housing and Urbanism and two representative small municipalities of Costa Rica, the Municipality of Santo Domingo in Heredia Province and the Municipality of Goicoechea in San José Province, where the resulting project outputs will be transferred.

The project is aimed at increasing the planning capacity and decision-making ability of small municipalities. It intends to adapt an existing GIS software package from the public domain in an attempt to ensure portability to different classes of microcomputers and accessibility for other small municipalities in the future.

Santo Domingo is a rural municipality located in an inter-urban corridor with a small but growing urban centre that serves as a focal point for surrounding villages. About twenty minutes by bus from San José, the population of the canton was 22 430 inhabitants in 1984. About 60% of Costa Rican municipalities have characteristics similar to Santo Domingo. Goicoechea is a highly urbanized municipality with fairly rural areas in its Northeastern part. This municipality is located about ten minutes from downtown San José. It had a population of 77 425 inhabitants in 1984. Although located within the metropolitan area of San José, it has the characteristics of most medium-size towns of the country. Some 15% of Costa Rica's municipalities are similar to Goicoechea.

In most developing countries, financial and human resources required by traditional ways of maintaining a master plan are out of the reach for small municipalities. Through the development and introduction of an efficient GIS tool in these municipalities, the project expects to overcome these constraints and therefore to allow a better decentralization of municipal development. The project has been building a microcomputer-based GIS from the public domain GIS software package, complemented by an Automated Mapping/Facility Management component, and interfaced with a commercial relational database management system. Municipal applications are studied and refined in collaboration with the Costa Rican central government Instituto Nacional de Vivienda y Urbanismo (INVU) and the two small representative municipalities serving as test sites for the project. The resulting GIS tool and databases will be transferred to these test municipalities to judge their performance and efficiency.

LOCAL-LEVEL MAPPING PHASE II, NIGERIA, 1989-1992

This project was developed by the Geography Department of the University of Lagos, Nigeria, in collaboration with the Geography Department of the University of Waterloo, Canada, as a second phase of the "Resource Mapping Sokoto-Rima Basin, Nigeria" project developed and carried out earlier by both institutions and financed by IDRC.

The first phase had developed a practical methodology to obtain basic resource information using remote-sensing data, in particular for the identification, assessment, and mapping of flood plains; for the assessment of land under cultivation during both the dry and wet

seasons; and for mapping and monitoring the extent of annual bush burning and firewood exploitation as well. This second phase expands on the earlier phase results, by concentrating on the development of a GIS-based method for the construction of land-capability mapping at the local scale in Northwest Nigeria. It involves the integration of high-resolution remote-sensing data with information from local farmers and data on institutional arrangements for water and land resources management. The project is envisaged as an experiment in the application of high-resolution remote-sensing imagery and GIS to the problems of integrated rural development in a semi-arid environment. It is designed to develop a methodology for the integration of local knowledge systems and space-borne remote-sensing and other data for land-capability mapping at the local level. The novel methodology to be designed for mapping land-capability will offer a great deal of potential for similar map production in different parts of the world. It is believed that, for the first time, a research project will attempt to synthesize and systematize the perceptions of local farmers on their environment with a view to producing a land-capability map using a GIS approach and remote-sensing data. So far, land-capability mapping has only dealt with physical parameters of land ecology, and this introduction of a local knowledge system concept represents a new approach. It certainly offers possibilities of meeting the expectations of many with regard to rural development information.

A Local Government Area located in a semi-arid environment (750 - 1 000 mm. rainfall per annum) with a prolonged dry season (October-May) in Sokoto State serves as the test site for the project. Sokoto-Rima is one of the 11 river basins in Nigeria and occupies the northwestern part of the country. The basin occupies some 102 000 km^2. Vegetation is dominated by mixed woodland. The economy of the area is principally subsistence agriculture and herding. Cropping is seasonal except in the river valleys, where seasonal flooding and the digging of wells enable year-round cropping.

GEOGRAPHIC INFORMATION SYSTEM FOR WATER RESOURCE MANAGEMENT, EGYPT, 1990-1993

This research project was developed by the Survey Research Institute of the Water Resource Centre of Egypt assisted by the GIS Division of the Surveys, Mapping, and Remote Sensing Sector of Energy, Mines and Resources Canada.

The project will directly contribute to the goals of the Egyptian Government relating to sub-urban and rural development in maintaining and even improving the crop production in alluvial soil along the Nile and in the Delta. Egypt, and most developing countries in the region, have a major deficit in food production. A significant proportion of necessary food is imported from developed countries. It is well known that, in the region, water is the limiting factor in crop production. When available, water still needs to be well managed, especially in the very light sandy soils of semi-arid lands. A water management strategy is a key element in maintaining and improving crop production.

The main objective of the project is to design and implement a GIS-based information system capable of handling and processing large amounts of spatial data from various sources for proper utilization in water resource management and decision-making. A GIS database and computer-aided facility, which will be applied to long-term resource management (irrigation, drainage and other soil and crop management) in Egypt, will be developed. Spatial hydrological models and sub-models will be tailored and integrated into the system.

The El-Mansuriya irrigated areas located in the close vicinity of Cairo, in Giza Governorate in the Nile Delta, serve as the pilot site. The total area covered by the study is approximately 700 hectares, and is characterized by the vegetable-producing terrain serving the Cairo market. The land is served by two distributary canals delivering water to smaller canals, or "mesquas", at the individual farm levels. The farmer must lift the water to irrigate his fields. Fields are very small averaging from 0.1 to 0.5 hectare. Two types of soil, alluvial clay and sandy soils are available in the area under study.

GIS FOR AGRICULTURAL DEVELOPMENT, MOROCCO, 1991-1994

This project was developed by the Institut national agronomique et vétérinaire (IAV) Hassan II of Rabat and the Direction provinciale de l'agriculture of Settat in collaboration with the Centre d'applications et de recherches en télédétection (CARTEL) of the Université de Sherbrooke.

Self-sufficiency in food in Morocco can be achieved by improving and stabilizing the agricultural production of its eight million hectares rain-fed farmland. Careful planning and the implementation of agricultural development programs on a regional scale require a systemic approach and a tool for the integration and day-to-day management of a reliable and up-to-date database. The overall aim of this project is to develop and implement a Geographic Information System for agricultural development which will aid in identifying strategies for developing rain-fed farmland for optimal use . The system will integrate data derived from various sources, maps, remote-sensing imagery, and statistics.

The system will be tested in a representative sample area of the Province of Settat, which includes five rural municipalities. The climate is of a semi-arid type with oceanic influence. The rainfall ranges from 390 to 410 mm. per annum and occurs mainly in winter (November-March). A large amount of data, including remote sensing, has already been made available to the project from former studies including the findings of the IDRC-funded project "Remote Sensing Contribution to Soil Mapping in Morocco".

GEOGRAPHIC INFORMATION SYSTEM FOR COASTAL AREA MANAGEMENT AND PLANNING, THE PHILIPPINES, 1991-1993

The project was developed by the International Centre for Living Aquatic Resources Management (ICLARM) and the National Economic Development Agency (NEDA) of the Philippines.

The tropical coastal environment in the Philippines is under severe stress. Over-exploitation of its vegetation, fisheries resources and coral reefs, erosion and sediment loads, habitat degradation and pollution threaten sustainable development of coastal zones. The overall objective of this project is to upgrade regional capabilities in coastal area planning and to establish an information system for storage and analysis of spatial and attribute data on coastal resources to facilitate planning and management of coastal areas through the application of a GIS. The GIS-based information system will be designed and implemented at one of the Regional Offices of the National Economic Development Agency (NEDA) of the Philippines. The project will also support the national initiative of decentralization of national administration.

The project will consolidate and analyze attributes and spatial data essential for coastal resources management, investigate usage of coastal resources, identify areas of intensive human activity and provide recommendations in policy guidelines for coastal resources management.

The selected test area is a region of the Lingayen Gulf with an area of 2 100 km^2 located in the northwestern side of Luzon Island facing the South China Seas and bounded by the provinces of Pangasinan to the west and La Union to the east. It is one of the major fishing grounds in the Philippines. The extensive coral reefs on the western side and the long stretches of beaches along the coasts make tourism one of the main economic sectors in the Gulf area.

GIS BASED ON REMOTE-SENSING (RS) DATA FOR SOIL AND WATER CONSERVATION IN TUNISIA, 1991-1994

This project was developed by the Ecole nationale d'ingénieurs de Tunis (ENIT) and the Direction de la conservation des eaux et des sols (DCES) of the Ministère de l'agriculture of Tunisia in collaboration with the Université Laval of Quebec.

The project is aimed at determining potential uses of GIS and RS data and techniques in rural engineering applications to soil and water conservation in Tunisia. It includes a study of information management issues dealing with inventory of natural resources degradation (soil, water and vegetation) in Tunisia and the establishment of a methodology of utilisation of these data and techniques to preserve these resources.

The project contains important technical research components in RS, GIS and in integrating these two technologies. In remote sensing, the project will contribute to improve the technique of segmentation for land cover mapping by exploring non-spectral information relevant to the classification of segments for the land-use theme. In GIS, the project will test the behaviour-driven (activity-driven) methodological approach in rural engineering information. This approach is quite different from data-driven and technology-driven approaches. It is, in fact, an approach close to the issue-driven one, which take into account the existing operational mode and mechanisms of the institution to address the issue under study. The project will test the step-by-step method for RS and GIS integration, from simple to more complex cases, based on available data, technology, models and expertise.

The project will also establish links with other IDRC-supported projects in the region, i.e. "Geographic Information System for Water Resource Management, Egypt" and "GIS for Agricultural Development, Morocco", both dealing with semi-arid and arid environment management. If appropriate, these links could evolve into a future regional network of GIS.

The selected test site for this study is the Oued Merguellil catchment basin (154 000 hectares) located in a semi-arid climate. Oued Merguellil, together with Oued Zeroud, collects waters of Central Tunisia from the Algeria-Tunisia border in the west to the city of Kairouan.

INTEGRATED MOUNTAIN RESOURCE MANAGEMENT, NEPAL, 1992-1994

This project will be carried out by the Integrated Survey Section (ISS) of Nepal and the University of British Columbia in Canada (see Soil Fertility and Erosion, Nepal, 1988-1991). In addition, the International Centre for Integrated Mountain Development (ICIMOD) will closely

collaborate by assisting ISS in linking their GIS database with the Mountain Environment and Natural Resources Information System (MENRIS) for data exchange, training and disseminating the project results.

This project will build on previous work done in the Jhikhu Khola watershed of the Nepal Mid-hills and is aimed at identifying and quantifying sources and rate of erosion; establishing sediment budgets; documenting indigenous knowledge on issues such as soil erosion control, soil fertility management, and sediment trapping; examining the linkages between grazing lands, forest and cultivated lands in relation to nutrient transfers; and developing new computer-based GIS models and methods which integrate socio-economic variables with bio-physical data.

Global Positioning System (GPS) technology will be used in conjunction with Rapid Rural Appraisal (RRA) techniques to spatially reference socio-economic data sets that are linked to land-use and ownership distribution. These data will then be incorporated into the GIS database and will facilitate the integration of socio-economic and bio-physical data in a spatially-referenced manner.

DISCUSSION AND CONCLUDING REMARKS

In addition to the development of specific tools, all these projects are aimed at developing knowledge of data collection and data processing mechanisms useful for technical studies; short-, medium- and long-term training of indigenous researchers, professionals and educators who are in charge of developing tools and their further utilization; and widespread dissemination of project results and methodologies developed to other interested developing countries through publications, meetings (local, national, and international), and exchange visits.

Requests for IDRC's support in applied GIS research have increased substantially. Similar increase has also been noted by other international agencies such as CIDA, USAID, SIDA, FAO, UNDP, UNEP, GTZ, etc. More than half of IDRC's Geomatics Program resources are allocated to GIS-applied research projects. Other programs within the Information Sciences Division, as well as within other Divisions of IDRC are beginning to demonstrate interest in GIS techniques and to integrate them as an appropriate tool for handling multiple-source information and for providing planning, engineering and decision-aid tools at various management and program levels in their respective sectors.

The Program's philosophy of development by enabling developing-world institutions and researchers to carry out applied research and development of technology and methods in building spatial data bases and extracting spatially-related information relevant for planning, management, development and administration seems fruitful to date. The research on GIS tools and methods has been used to complement other sectoral IDRC initiatives with a view of enhancing indigenous capability by integrating spatial information systems into project planning and implementation. It has also looked at providing technology appropriate to the developing countries needs, limitations and modus operandi. It has fostered GIS technology transfer within developing countries, in order to build core and networked expertise. IDRC-funded projects have also stimulated the enhancement of communication and interaction between developing-country and Canadian researchers and institutions.

From a technical point of view, the use of microcomputer-based GIS packages has been found adequate to meet the research objectives of IDRC-supported projects, for all of the packages used. With adequate exposure to automated data handling and cartography, learning

of GIS technology is within the reach of sectoral specialists. Short-term courses seem sufficient for the purpose of presenting the concepts of GIS, the development of geographic databases, and most basic system operation functions.

Unexperienced GIS users tend to underestimate the efforts and time required to build a geographic database. This is particularly the case in developing countries where little digital spatial data is available. In many cases, the access to large scale printed maps, when they exist, is difficult. Remote-sensing data offer a partial solution to this problem. Many variables can be extracted from this source in machine-readable form, therefore the user must be trained on remote-sensing image processing technology.

Research in GIS technology in developing countries should concentrate in the future at developing novel applications; building and sharing of geographic databases; and at interfacing GIS packages with other computer-based tools.

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TITRE: Limite inférieure des fracrtures ouvertes dans le socle et relations entre linéaments et réseau hydrographique dans le bassin versant de la Haute Marahoué (Côte d'Ivoire), à l'aide de la Télédétection numérique et du SIG.

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RÉSUMÉ

L'intégration, au système d'information hydrogéologique à référence spatiale (SIHRS), des courbes altimétriques et le calcul d'un modèle numérique d'élévation du bassin versant de la Haute Marahoué, ont permis de confectionner un bloc diagramme ayant servi à l'étude des limites inférieures des fractures ouvertes; et, du profil d'altération dans le socle cristallin capté par de nombreux forages dans la région.

Des mégafractures d'importance régionale dans le socle africain et d'orientation: N170-190; N30-60; N80-100 et N120-160 , caractéristiques de la tectonique cassante en Afrique de l'Ouest, ont été relevées sur une superficie de 12 500 km^2.

A l'interieur du SIG, une étude sectorielle des rélations entre les accidents et le réseau hydrographique, sur le granite circonscrit de Séguéla, a révélé que les principaux cours d'eaux circulent essentiellement dans les axes tectoniques.

Une généralisation de cette étude, a permis d'établir les cartes de fracturations du bassin versant de la Marahoué et de la Côte d'Ivoire.

ABSTRACT

Title - The breaking opens lower limit in the bed-plate and the relationships between lineaments and hydrographical network in the river-bassin from Upper Marahoue (Côte d'Ivoire), using numerical remote sensing and GIS.

The integration to the Hydrogeological Information System with Spatial Reference (HISSR), for the altimetrical curves and the calculation of a numerical model of the basin rise from the Upper Marahoue, has allowed the making up of a diagram block which has been used in the study of the breakings-open lower limits and for the adulteration profile in the crustalline bed-plate captured by several welles in the region.

Some megabreakings of regional importance in the africcan bed-plate and of landmark indicatiors: N170-190; N30-60; N80-100 and N120-160, caracteristics of the sharp tectonic in west Africa , have been collected on an area of 12500 km2.

At the interior of HISSR, a sectorial study of the relationships between the irregularity of the ground and the hydrographical network, on the granite localized in Seguela area, has revealed that the main water courses run essentially in the tectonical axes.

A generalization of this study has allowed us to establish the breakings-open cards of the basin from the Upper Marahoue and Côte d'Ivoire.

INTRODUCTION

En Côte d'Ivoire, en dehors du bassin sédimentaire cotier, les principales ressources en eaux souterraines se situent dans les roches fissurées du socle précambrien et dans les altérites déjà exploitées par la plupart des puits villageois. Les innombrables forages réalisés ces dernières années captent les eaux souterraines à des profondeurs parfois importantes puisque fréquemment de l'ordre de 80 à 120 mètres, aussi bien dans les granites ou les migmatites que dans les assises volcanosédimentaires du Birrimien, au niveau de fissures souvent ouvertes, dans lesquelles, les eaux peuvent être en charge.

A l'heure actuelle, il est devenu important pour la Côte d'Ivoire, pour la gestion de ces eaux souterraines, de connaître non seulement leurs caractéristiques physicochimiques, bactériologiques et hydrodynamiques; mais aussi, leur origine; et, de savoir, s'il s'agit d'eaux anciennes, difficilement renouvelables, à travers les réseaux de fractures mal connectés et ne représentant que des réserves limitées, ou d'eaux récentes, régulièrement renouvellées, dans des fissures peu profondes et donc exploitables à long terme.

SECTEUR D'ETUDE ET DONNEES DE BASE

Le secteur d'étude, le bassin de la Haute Marahoué présente toutes les caractéristiques typiques d'une zone sub-sahélienne d'Afrique de l'Ouest, touchée, par le problème d'eau. Il est compris entre les latitudes 7°40' et 9°30' N et les longitudes 6° et 7° O et couvre une superficie de 12 500 km^2 .

Les images satellites proviennent du capteur Thematic Mapper de Landsat 5. Elles ont été acquises en janvier 1986, en saison sèche (scène 198-54, quadrant 2 et 4; scène 197-55, quadrant 1 et scène 197-54, quadrant 3) et les données géocodées du champ magnétique total, dont la dimension des pixels est de 125 par 125 m.

METHODOLOGIE

Afin de visualiser les nombreuses fractures qui affectent le socle dans le secteur d'étude, différentes techniques de traitement numérique ont été retenues pour le rehaussement des images: rapports et combinaisons entre différentes bandes TM, classification semi-dirigée, filtrage directionnel de Sobel utilisant la matrice 7 x 7, etc. Pour l'interprétation visuelle des structures géologiques et linéamentaires, il a été retenu les composantes principales, le rapport TM7-TM4 / TM7+TM4 et la combinaison TM6+TM7.

.Ce travail a nécessité la création d'un système d'information hydrogéologique à référence spatiale (SIHRS), auquel il a été intégré les courbes altimétriques yant servi à la confection du bloc diagramme, mais également de nombreuses données de base comme: les dérivées des images satellitaires réhaussées (classification géologique, cartes linéamentaires, etc); les données géocodées du champ magnétique total de Kenting Sciences acquises en 1974 et 75; les cartes d'interprètation géologique des données aéromagnétiques de la Société Paterson, Grant et Watson 1977 à 1/200.000; les principaux cours d'eau, le réseau routier et la localisation des villes et villages (recueillies sur des cartes topographiques au 1: 200 000).

La base de données comporte également un ensemble de paramètres hydrauliques (profondeur totale des ouvrages, épaisseur des altérites, profondeur et épaisseur du socle sain traversé, débits , transmissivités, arrivées d'eau); des paramètres physico-chimiques (température, pH, conductivité, turbidité et matières en suspension; des cations : Ca, Mg, Na, K, NH4 et Fe et anions : HCO3, Cl, SO4, NO3, NO2 et

PO4); des teneurs isotopiques en tritium, oxygène-18 et deutérium et des données de la géophysique et de la géologie de terrain.

RESULTATS ET INTERPRETATION

L'utilisation simultanée des techniques de traitement numérique d'images satellitaires et d'un système d'information hydrogéologique à référence spatiale, a été concluante pour la conception d'un modèle numérique d'élévation du bassin; l'établissement d'une carte des variations des pourcentages de pente; l'identification du contour exact du granite circonscrit de Séguéla et de la forme effilée, entre les granites et les granito-migmatites, du sillon intracratonique birrimien de Boundiali

L'exploitation des ressources du SIHRS a permis, également, d'étudier les relations: linéaments -positionnement et productivité des forages; ce qui a contribué à la mise au point d'un moyen efficace de contrôle des programmes d'hydraulique villageoise, la "croix de survie" des forages en milieu de socle fissuré, pouvant ultérieurement intervenir dans les études d'implantation des forages dans le socle. Certains de ces résultats ont déjà fait l'objet de communications scientifiques présentées lors des assises du 7ème congrès de l'AQT, tenu à Montréal, du 23 au 25 octobre dernier.

Par conséquent, cet article sera consacré à l'évolution, dans un bloc diagramme confectionné dans le SIHRS, des mégafractures ouvertes en profondeur dans le socle cristallin et des relations entre réseaux de linéaments et réseaux hydrographiques, point d'appui à l'établissement d'une carte générale de fracturations en Côte d'Ivoire.

• BLOC DIAGRAMME ET LIMITE INFERIEURE DES FRACTURES OUVERTES DANS LE SOCLE

Un bloc diagramme du bassin versant de la Haute marahoué, confectionné grâce aux mulitiples fonctions du SIHRS., permet de suivre, l'évolution apparente des arrivées d'eau et des débits optimums; ainsi que la progression, en profondeur dans le socle, du front d'altération, dont l'épaisseur assez faible au Nord du bassin (10 à 20 m), gagne en importance dans le secteur Sud où elle avoisine les 70 m (Figure 1) .

En Afrique, les spécialistes en sciences de l'eau admettent généralement que les arrivées d'eau décroissent en nombre et en importance avec la profondeur du socle sain traversé. Certains auteurs fixent à 50-60 mètres, la limite inférieure d'existence des fissures ouvertes. Dans le bassin de la Haute Marahoué, des résultats similaires, observables dans le bloc diagramme, laissent plutôt planer un doute.

Même si, l'évolution des débits optimums, des arrivées d'eau et des pourcentages des fractures en profondeur, tend à mettre en évidence, à partir de 90 à 100 m, l'existence d'une limite inférieure apparente des fractures ouvertes dans le socle, ce résultat doit être pris avec prudence, à cause d'un biais éventuel pouvant exister dans la façon d'appréhender ce problème. Car, dans le bassin, la majorité des forages ne dépasse pas 50 m de profondeur; tant et si bien que, la regression du nombre des arrivées d'eau que l'on constate au-delà de 100 m, est susceptible de traduire aussi une insuffisance en nombre des forages atteignant cette profondeur extrême dans la région .

• CARTE DES FRACTURATIONS

La carte des linéaments comporte près de 16 000 segments assimilables à des fractures Les linéaments ont été identifiés sur les images Landsat TM réhaussées décrites plus haut, en exploitant les possibilités du SIHRS Les linéaments, d'importance régionale associés aux accidents majeurs dans le socle, ont principalement été identifiés à l'aide de la combinaison TM6+TM7 et du filtrage directionnel de Sobel utilisant la matrice 7 x 7. Toutes les discontinuités - images observées se répartissent selon les principales directions tectoniques d'Afrique: N170-190°, N80-100°, N30-60° et N120-160°.

Des cassures de grande importance dans le socle s'observent dans presque dans toutes les régions du bassin, où ils présentent les caractéristiques de véritables couloirs de cisaillement (shear zone): couloirs de cisaillement de Séguéla (N180°); Morondo (N35°); Gbominasso (N50°); Kani (N40°); Bobi (N73°); Dianra (N123°) et de Mankono (N120°) qui se font accompagnés, secondairement, par plusieurs systèmes de failles.

La plupart de ces accidents ont connu des phases de réactivation depuis le Crétacé à maintenant , ce qui se traduit par des manifestations périodiques des tremblements de terre d'importance encore mineure en Côte d'Ivoire et en Afrique de l'Ouest; à l'exception du séisme de Gaoul en Guinée en décembre 1983, d'amplitude 6,4, dont les secousses ont largement été ressenties dans le Golfe de Guinée. Le foyer sismique de ce séisme est situé sur un faisceau d'accidents NO-SE qui se prolonge en Côte d'Ivoire par le couloir de cisaillement de Dianra -Niakaramadougou.

Les traces du couloir de Dianra -Niakaramadougou sont visibles jusqu'au Ghana, à la hauteur des monts Akuapem qui représente une zone à haut risque de sismicité dans ce pays. De même, les traces du couloir de Séguéla, sont reconnaissables sur plus de 1500 km, depuis l'Océan Atlantique (au Sud), jusqu'au Mali (au Nord).

• RELATIONS: LINEAMENTS - RESEAU HYDROGRAPHIQUE

A l'interieur du SIHRS, l'étude des relations entre les accidents relevés en images satellitaires et le reseau hydrograpysique, dans le secteur couvert par le granite circonscrit de Séguéla, montre que la Marahoué et le Yarani coulent dans deux faisceaux d'accidents N-S et E-W, dont le point de croisement à angle droit, correspond à la confluence des deux rivières. Dans ce secteur, tous les bras de cours d'eau coulent dans une fracture affectant le granite, ce qui donne ainsi, une parfaite similitude entre le réseau hydrographysique et celui des linéamants satellitaires (Figure 2).

Ces résultats sont conformes à l'état des connaissances acquises en Côte d'Ivoire et d'une manière générale en Afrique de l'Ouest, sur le rôle joué par les accidents dans le guidage des cours d'eau.

En effet, dans le bassin versant de la Haute Marahoué, les principaux fleuves s'installent toujours, tout au moins en grande partie, dans les fractures majeures, signalées plus haut, et, qui sont des axes dominants de drainage tant pour les eaux superficielles que souterreaines (Figure 3).

- Cas des accidents N-S

La présence du couloir subméridien de Séguéla est sensible, au Nord du bassin, le long d'un axe passant, du Sud au Nord, par les villages de Siakasso, Komatou, Lipara, Faligaha et Biya, où le Yarani et ses affluentsces coulent dans le sens N-S. L'influence de ce couloir de cisaillement est également assez nette sur le tracé de la Marahoué et ses affluents. Les traces de l'accident de Séguéla débordent largement les

limites du bassin: au Sud , elles sont visibles sur les rivières Lobo, à la hauteur de Daloa ; et , sur la rivière Sanpédro, au point où cette dernière se jette dans la mer ; au Nord, ce couloir oriente la rivière Mahandiabani, depuis le mont Kouorouba, près de Boundiali, jusqu'au Mali.

- Cas des accidents E-O

Au Sud du village de Forotoutou, l'accident de Souasso-Forotoutou, d'orientation E-O, intervient dans le guidage de la rivière Saouo qui se jette dans la Marahoué vers l'Est. Cette rivière est parallèle à une seconde (Farolodya), passant par Kani. Plus au Sud, le Yarani se jette dans la Marahoué, grâce à une importante fracture E-O.

- Cas des accidents NE-SO

Les accidents de cette direction n'influencent que très faiblement le réseau hydrographique. Leur guidage se limite à des rivières de moindre importance. Par exemple, le couloir de Kani n'influence que le Kohouê et le Kouroumbo.; et ceux de Morondo et de Gbominasso quelques rivières d'ori,entation NE-SO. Dans la région de Sarhala, la disposition parallèle des rivières NE-SO résulterait, de la présence dans ce secteur, des accidents de même direction. Toutefois, les traces du couloir de Morondo sont observables, depuis le mont Patu Range du Libéria, jusqu'au Mali et au Burkina Faso.

- Cas des accidents NO-SE

Entre Morondo et Dianra, le changement de direction qui affecte le tracé de la Marahoué, passant du NS à NO-SE, est attribuable au grand couloir de Dianra. Les traces de ce dernier sont visibles sur de nombreux petits cours d'eau, entre Dianra et Siréba, au Nord-Ouest du Bassin, et même jusqu'en Guinée et sur la rivière Sankarani, coulant dans le prolongement des accidents majeurs de Gaoual. Le couloir de Mankono oriente, indiscutablement, les rivières de Kongou, Youho et Gbara , entre Sarhala et Djibroso.

Ainsi, il existe une parfaite concordance entre les directions tectoniques majeures, relevées en images satellitaires, et , le comportement du réseau hydrographique au sol. Les accidents NO-SE et N-S sont les principaux axes de drainage des eaux de surface. Ils guident généralement les fleuves les plus importants. A l'opposé, la direction NE-SO n'influence que les affluents d'importance secondaire.

Ces résultats peuvent être utilisés dans l'estimation de l'âge des accidents et également des fleuves. Les fleuves les plus importants (Marahoué et Yarani) sont postérieurs aux accidents NO-SE et N-S qui les logent et antérieurs à ceux de direction NE-SO avec lesquels ils n'entretiennent aucune relation.

Du point de vue hydrogéologique, la grande capacité des fractures NO-SE à contenir de l'eau dans ce bassin, s'explique par leur grande tendance à l'ouverture, du fait de leur direction voisine de celle de la contrainte maximale actuelle, en rapport avec les phases actuelles de reactivation qui caractérisent ces accidens libériens d'Afrique. Au contraire, l'insuffisance des débits dans les forages captant les fractures d'orientation NE- SO, est la conséquence de l'âge relativement récent de ces accidents, non encore sollicités, de façon importante, par la remobilisation.

En généralisant cette étude à l'ensemble du bassin versant de la Marahoué et à toute la Côte d'Ivoire , il a été possible d'établir les cartes defracturations de tout le territoire national. Car, d'une façon générale, l'influence du réseau hydrographique est sensible sur la plupart des mégafractures affectant le socle africain. (Figure 4).

CONCLUSION

Dans le bassin de la Haute Marahoué, l'étude des phénomènes d'altération et de fracturations, à l'aide de la télédétection numérique et d'un système d'information à référence spatiale, montre que l'épaisseur du front d'altération est assez faible dans le secteur Nord (10 à 20 m); alors qu'à l'opposé, elle gagne en importance dans le Sud où elle avoisine les 70 m.

L'évolution des débits optimums, des arrivées d'eau et des pourcentages des fractures en profondeur, tend à mettre en évidence, à partir de 90 à 100 m, l'existence d'une limite inférieure apparente des fractures ouvertes dans le socle,.comme le pensent les anciens auteurs. Mais, ce résultat doit être pris avec prudence, à cause d'un biais éventuel pouvant exister dans la façon d'appréhender ce problème. Car, souvent (cas du bassin de la Haute Marahoué), la majorité des forages ne dépasse pas 50 m de profondeur; tant et si bien que, la regression du nombre des arrivées d'eau que l'on constate, au-delà de 100 m, est susceptible de traduire aussi, une insuffisance en nombre des forages atteignant cette profondeur extrême dans la région .

Des cassures de grande importance dans le socle, véritables couloirs de cisaillement (shear zone) comme ceux de Séguéla (N180°); Morondo (N35°); Gbominasso (N50°); Kani (N40°); Bobi (N73°); Dianra (N123°) et de Mankono (N120°), qui se font accompagnés, secondairement, par plusieurs systèmes de failles, ont connu des phases de réactivation, depuis le Crétacé à maintenant , ce qui se traduit par des manifestations périodiques des tremblements de terre, d'importance encore mineure en Côte d'Ivoire et en Afrique de l'Ouest; à l'exception du séisme de Gaoul en Guinée, en décembre 1983, d'amplitude 6,4. Ces phases actuelles de remobilisation affectent surtout les accidents NO-SE.

Par conséquent, du point de vue hydrogéologique, la grande capacité des fractures NO-SE à contenir de l'eau dans ce bassin, s'explique par leur grande tendance à l'ouverture, du fait de leur direction voisine de celle de la contrainte maximale actuelle, en rapport avec les phases actuelles de reactivation qui caractérisent ces accidens libériens d'Afrique. Au contraire, l'insuffisance des débits dans les forages captant les fractures d'orientation NE- SO, est la conséquence de l'âge relativement récent de ces accidents, non encore sollicités, de façon importante, par la remobilisation.

En généralisant l'étude des relations entre les linéaments et le réseau hydrographique , il a été possible d'établir la carte de fracturations de la Côte d'Ivoire basée sur le fait que, d'une façon générale, l'influence du réseau hydrographique est sensible sur la plupart des mégafractures affectant le socle d'Afrique.

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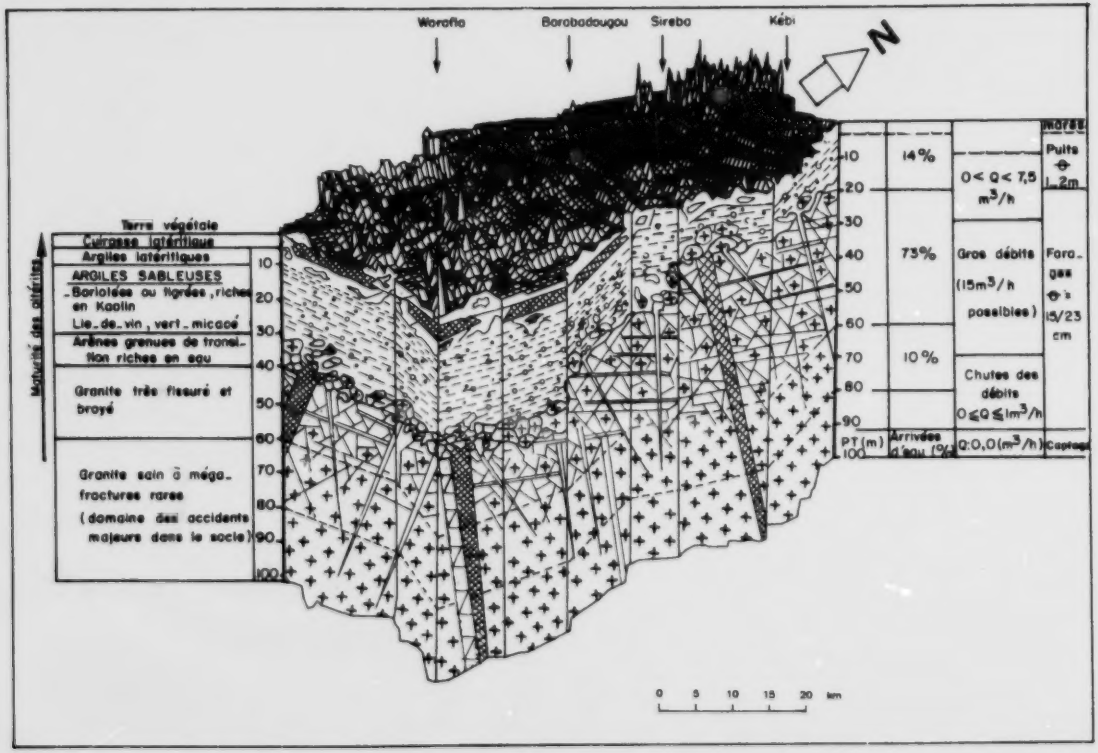
Figure 1: Bloc diagramme du bassin versant de la Haute Marahoué,, établi par intégration des courbes altimétriques et le calcul du modèle numérique d'élevation de la région à l'intérieur du SIHRS


Worofla
Barabadougou
Sireba
Kébi
N
Terre végétale
Cuirasse latéritique
Argiles latéritiques
ARGILES SABLEUSES
- Bariolées ou tigrées, riches en Kaolin
Lie-de-vin, vert-micacé
Arènes grenues de fronteil-lon riches en eau
Granite très fissuré et broyé
Granite sain à méga-fractures rares
(domaine des accidents majeurs dans le socle)
Maturité des altérites
10
20
30
40
50
60
70
80
90
100
PT (m)
14 %
73%
10 %
Arrivées d'eau (%)
0 ≤ Q ≤ 7,5 m³/h
Gros débits (15m³/h possibles)
Chutes des débits 0 ≤ Q ≤ 1m³/h
Q: 0,0 (m³/h)
Forages
Puits ⌀ 1,2m
Forages ⌀ 15/23 cm
Captage
0 5 10 15 20 km

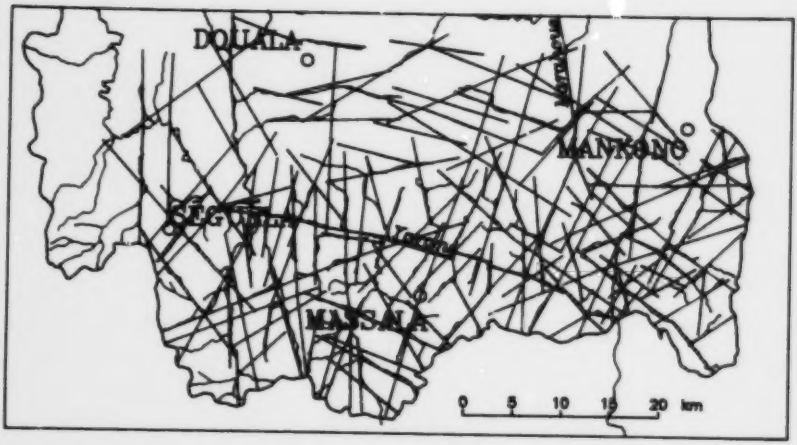
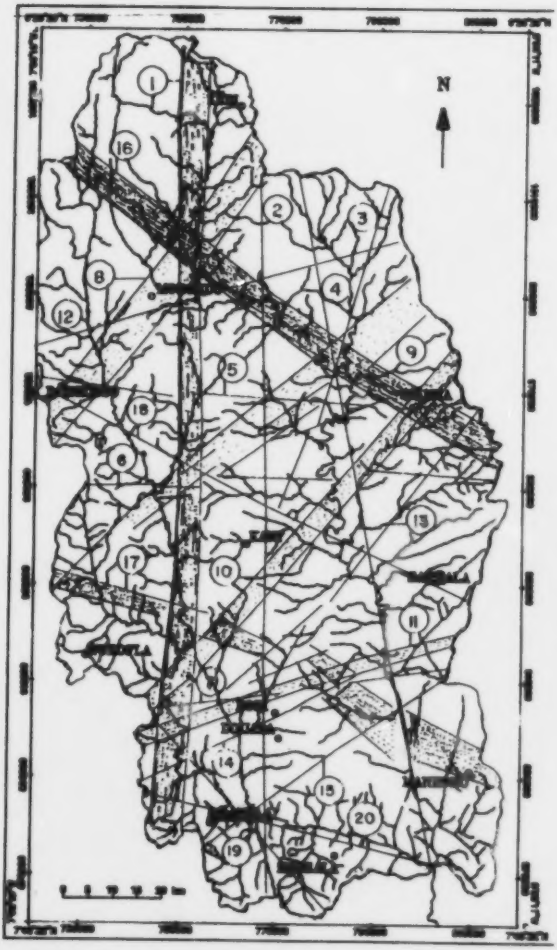


Figure 2: Relations entre réseau hydrographique et réseau de fractures affectant le granite circonscrit de Séguéla , interprètées à l'intérieur du SIHRS



Couloirs de cisaillement

1-Séguéla
8-Morondo
9-Gbominasso
10-Kani
11-Bobi
16-Dianra
17-Mankono

Failles importantes

2- Massala
3- Yérétyélé
4- Karamokola
5- Kondogo-Ouakro
6- Souasso-Forotoutou
7- Kénégbé-Bayani
12-Djibros
13-Faraba
14-Douala
15-Nandaala
18-Sarhala
19- Gbokolo
20- Marhana

Figure 3: Relations entre réseau hydrographique et réseau d'accidents majeurs affectant le socle cristallin dans le bassin versant de la Haute Marahoué, interprètées à l'intérieur du SIHRS.

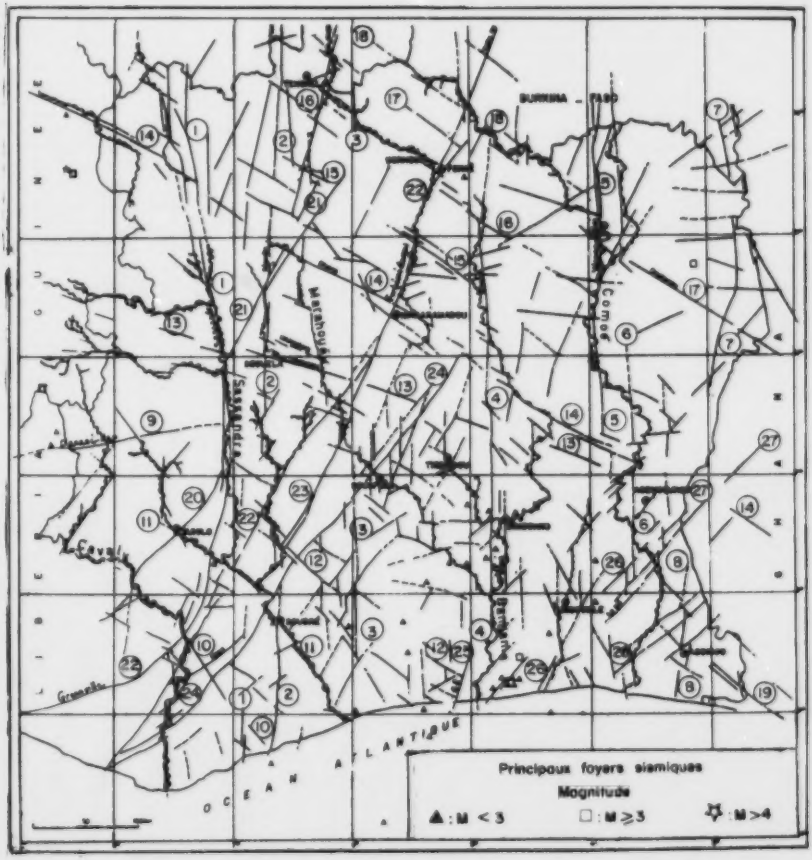


Figure 4: Relations : réseau hydrographique - accidents majeurs - foyers sismiques dans le socle cristallin de Côte d'Ivoire, établies à partir d'une généralisation des rapports cours d'eau - fracturations interprétés à l'intérieur du SIHRS.

Failles Nord-Sud (1: Sassandra; 2: Séguéla; 3: Gagnoa; 4: Ndouci-Dimbokro-Brobo; 5: Wango-Fitini; 6: Abengourou; 7: Bouna; 8: Ayamé); Failles Est-Ouest (9: Danané-Man); Failles NW-SE (10: Taï; 11: Soubré; 12: Guibéroua; 13: Marhana; 14: Dianra-Niakaramadougou; 15: Boundiali; 16: Tengréla-Ferkessédougou; 17: Mt Boutourou; 18: Ferké; 19: Aboisso); Failles NE-SW (20: Guiglo; 21: Morondo; 22-23: Greenville-Niakaramadougou-Ferkessédougou; 24: Bouaflé; 25: Gô; 26: Agboville; 27: La Mé; 28: La Bia)

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CMOIG,
Activité du sous comité sur la recherche et la formation : 1991

A. N. Renz

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Phyllis B. Charlesworth

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TITRE: Apports de la télédétection et d'un système d'information géographique à l'étude des perméabilités induites par les fractures et des couloirs souterrains d'écoulement d'eaux dans le socle cristallin de la Haute Marahoué (Côte d'Ivoire).

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RESUME

Les écoulements et les possibilités de formation des réservoirs d'eaux dans les milieux fissurés, peuvent être appréhendés, grâce à l'étude des perméabilités induites par les fractures (.Franciss, O., 1970). Cependant, jusqu'à maintenant, les résultats obtenus par cette technique sont restés tributaires de l'importance et surtout de la densité des fractures susceptibles d'être visualisées sur les photographies aériennes classiques.

Les images Landsat TM, du bassin versant de la Haute Marahoué, traitées numériquement et interprètées à l'intérieur d'un système d'information Hydrogéologique à référence spatiale (SIHRS), ont considérablement amélioré cette approche, grâce à une assez forte densité de fractures (62 fractures en moyenne par 1,44 km2 de surface), repérable sur les images satellitaires réhaussées. En effet, .les valeurs de perméabilités induites, obtenues par ce procédé, varient de 0,11 à 0,66.10-4 m/s; contre des valeurs de 10^{-8} m/s par les méthodes classiques. Par conséquent, elles sont voisines des perméabilités réelles des terrains fissurés affectés par l'altération.

Les variations spatiales des perméabilités induites étudiées à l'intérieur du SIHRS ont révélé que l'alimentation des aquifères, qui se fait à travers les axes tectoniques de drainage bien devéloppés, est plus intense sur la bordure Ouest que dans la partie orientale du bassin et que les accidents majeurs logent les principaux cours d'eau de la région.

ABSTRACT

Title- Contribution of remote sensing and of a geographic information system to the study of permeabilities induced by fractures and underground corridors for water flow in the cristalline basement of the Upper Marahoue (Côte d'Ivoire).

Flows and water reservoir formation possibilities in cracked environments may be checked by the study of permeabilities induced by fractures (Franciss, O., 1970). However, up to now, results obtained by this technique have been function of the importance and especially the density of fractures that might be observed on classical aerial photographs.

Landsat TM imagery, of the Upper Marahoue water basin , numerically treated and interpreted within a Hydrgeological Information System with Spatial Reference (HISSR), have considerably improved that approach, thanks to a rather high density of fractures (62 fractures on the average per 1.44 km2), seen on the enhanced satellite images. Indeed, values of induced permeabilities, obtained through that procedure, vary from 0.11 to 0.66. 10^{-4} m/s, as compared with values of 10^{-8} m/s obtained by classical methods..Consequently, those values are close to actual permeabilities of cracked terrains affected by weathering.

Spacial variations of induced permeabilities studies within HISSR have shown that, the alimentation of aquifers through well developed tectonic axes for drainage, is more intense on the western edge than on the eastern edge of the basin and that major accidents house the main streams of the region.

Introduction

Depuis plusieurs décennies, le continent africain et en particulier la zone soudano-sahélienne, connait des épisodes assez fréquents de sécheresse dont le paroxysme fut atteint dans les années 1972-73.

A cette époque, les conséquences désastreuses de cette calamité naturelle, n'ont épargné aucun pays d'Afrique de l'Ouest, où l'on a enregistré, un tarissement généralisé de la majorité des points d'eau de surface; et, une baisse souvent importante du niveau piézométrique des nappes phréatiques, mettant du coup à sec, tous les puits creusés dans les profils d'altération au toit du socle cristallin.

Devant cette menace cyclique contre la vie des populations, nombre des états du continent, se sont dotés, à partir de 1973, de moyens puissants pour l'exécution des forages d'eau sur leur territoire respectif. C'est le cas de la Côte d'Ivoire qui totalise, à la fin de 1983, sur son territoire national, plus de 13.000 ouvrages de captage d'eau, d'un montant global excédant les 400 millions de dollars CAD.

Malheureusement, ces forages d'eau ont été réalisés avec une précipitation assez grande et pour cause: la sécheresse était là, les populations avaient bésoin d'eau pour survivre; tant et si bien que l'urgence des bésoins humains à couvrir justifia les insuffisances souvent constatées: tâtonnements fréquents et pertes énormes en temps, en argent et en matériels.

C'est pourquoi, en 1985, le gouvernment de Côte d'Ivoire décida d'approfondir ses connaissances scientifiques sur les potentialités en eau des aquifères de fissures du socle précambrien, qui réprésente, à lui seul, 97% du territoire national.

OBJECTIFS

Ce projet a été a été exécuté par l' Université Nationale de Côte d'Ivoire et le CARTEL de l'Université de Sherbrooke, grâce à un financement du Centre de Recherche pour le Développement International (CRDI). Les principaux objectifs initialement visés sont les suivants :

- améliorer l'utilisation des techniques de télédétection dans l'étude des aquifères de socle cristallin;
- créer un système d'information hydrogéologoique à référence spatiale (SIHRS) pour mieux gérer les multiples informations relatives aux aquifères captés par les ouvrages en milieu fissuré;
- mettre au point des méthodologies simples, efficaces et rapides pour faciliter la découverte des réservoirs, les études d'implantations et de gestion des forages dans le socle.

CHOIX DU SECCTEUR D'ETUDE

Le bassin versant de la Marahoué a été choisi comme bassin témoin à cette étude. Il a été choisi parce qu'il présente toutes les caractéristiques typiques des régions subsahéliennes, les plus touchées par les problèmes de manque d'eau en Côte d'Ivoire: en effet, en 1984-1987, les observations de terrain, faites lors des missions de reconnaissance, ont révélé que, sur 212 forages mis en expliotation dans le bassin:

- 48 forages (22,6%) étaient régulièrement en panne mécanique,
- 18 (8,4%) abandonnés pour le mauvais goût de leur eau ou pour leur situation dans un bois sacré destiné à des cultes rituels
- 39 (18,39%) complètement sans eau.

Au total, ce sont environ 50% des ouvrages réalisés qui n'étaient pas constamment fonctionnels pour une raison ou une autre, exposant les populations à des besoins importants en eau.

Ce bassin s'inscrit entièrement au Sud du cadran NW de la Côte d'Ivoire, à l'intérieur d'un rectangle de 240 km de long et 50 km de large (soit environ 12.500 km^2 de surface) dont il occupe toute la partie diagonale. Ce bassin est limité par les latitudes 7°40' et 9°30' N et les longitudes 6° et 7°W. Le cours d'eau principal, la Marahoué est encadré par deux affluents : le Béré à l'Est et le Yarani ou Banoroni à l'Ouest. il se jette dans le Bandama blanc peu après la ville de Bouaflé, au niveau du village de Bozi.

PRESENTATION DES DONNEES SATELLITAIRES, REHAUSSEMENT DES IMAGES ET INTEGRATION DES DONNEES AU SIHRS

Trois scènes Landsat Thematic Mapper se recoupent sur le bassin versant de la Haute Marahoué: les quadrants 2 et 4 de la scène 198-54, le quadrant 1 de la scène 197-55 et le quadrant 3 de la scène 197-54. Ces images ont été acquises en l'absence de nuages, au coeur de la saison sèche, les 7 et 16 janvier 1986. La création de la mosaïque a nécessité un calibrage radiométrique (ajustement de la moyenne et de l'écart-type entre les secteurs de recouvrement). La correction géométrique comporte un rééchantillonnage de la taille des pixels à 50 x 50 mètres, compte tenu de la grande superficie du bassin. Les bandes 3 (rouge), 4 (proche infrarouge), 5 (infrarouge moyen), 6 (infrarouge thermique) et 7 (infrarouge lointain) ont été retenues.

La base de données comprend les images du champ magnétique total résultant d'une mission aéroportée effectuée au cours des années 1974 et 1975 par la Kenting Earth Sciences Ltd. Ces données, interpolées et géocodées, ont été acquises de la Commission Géologique du Canada. La taille des pixels est de 125 m x 125 m. A ces images, s'ajoutent les cartes topographiques (1: 200 000) et les informations géologiques préexistances ou recueillies (Millary, 1964; DCH, 1982; SODEMI,1971-72 et études géologiques à l'affleurement).

Les traitements d'images ont porté sur la recherche d'une meilleure combinaison d'images déjà rehaussées, susceptibles de favoriser une la discrimination des ensembles lithologiques et une perception des linéaments sur les compositions colorées. Ainsi, cette étude a été menée à partir des composantes principales, du rapport TM7-TM4 / TM7+TM4, de la combinaison TM6+TM7 et des filtres directionnels de Sobel utilisant une matrice de 7 x 7.

Les images satellitaires réhaussées et du champ magnétique total, couplées avec les données géologiques, ont été intégrées numériquement au système d'information à référence spatiale où l'on a produit, par superposition et interprétation des images, la carte des réseaux de linéaments du bassin. A partir de cette dernière, il a été entrepris l'étude des perméabilités induites par les fractures et des prinicipaux couloirs souterrains de circulation d'eau.

PRINCIPE DE CALCUL DES PERMEABILITES INDUITES PAR LES FRACTURES

La méthode de Franciss n'est applicable qu'aux régions où le socle est affecté par des fractures voisines de la verticale; comme c'est le cas dans le bassin de la Haute Marahoué, où les structures cassantes présentent, dans 80% des cas, des pendages généralement supérieurs à 80°, à l'instar de leurs homologues du Yaouré , un secteur situé plus au Sud (R. Fabre, 1985)

Le calcul de perméabilités induites par les fractures a necessité, au laboratoire, un maillage du bassin de la Haute Marahoué, d'une superficie de 12 500 km2, en 103 cercles de 12 000 mètres de diamètre, inscrit chacun à l'intérieur d'un carré dont le côté est égal au diamètre du cercle correspondant. A l'intérieur de chaque cercle, il a été calculé:

- le nombre total
- la longueur individuelle et totale
- et l'orientation cas par cas des fractures

Au préalable, des mesures effectuées à l'affleurement ont permis d'estimer deux variables indispensables au calcul des perméabilités induites: la conductivité hydraulique (Kf)

de la région et le coefficient empirique de proportionalité entre l'ouverture et la longueur des fractures (C).

La conductivité hydraulique (K_f) est assimilable à la perméabilité moyenne apparente caractérisant toute la surface étudiée. A partir de l'expression de la transmissivité dans une zone fracturée traversée par un forage:

$$Ki = Ti = K_i e_i$$

avec:

T	=	transmissivité (m2/s) de la zone
e	=	épaisseur de la zone
K_i	=	conductivité de la zone

Cette variable est donnée par la relation:

$$K_f = \left(\Sigma \frac{T_i}{e_i} \right)$$

Dans les forages à arrivées d'eau multiples, l'épaisseur de la zone fracturée peut être estimée à partir de la différence de profondeur entre la première et la dernière arrivée d'eau.

Les valeurs de la transmissivité ont été calculées à partir des essais de pompage réalisés sur 80 forages, par les méthodes d'approximation de Jacob, Cooper-Jacob, Gringarten et Thiery.

Dans le cas de la variable (C), le problème de la mégafracture visible en image satellitaire peut être envisagée à deux dimensions parce que l'épaisseur de la croute terrestre fracturée est très négligeable par rapport à son étendue. En général, cette épaisseur ne dépasse guère 100 m pour 10 Km^2 de surface, autrement dit elle varie dans un rapport $<10^{-5}$. En conséquence, l'épaisseur de la zone broyée peut être considérée comme une fonction linéaire empirique de la longueur apparente de la mégafracture telle que :

$$e = CL$$

avec:

e	=	épaisseur de la zone broyée (m)
L	=	longueur apparente de la mégafracture mesurée en photographie aérienne (m)
c	=	coeficient de proportinalité empirique.

La variable (C) a été déterminée empiriquement en mesurant les longueurs et les ouvertures sur environ 2000 fractures mesurées dans le bassin et en faisant le rapport entre les deux paramètres.

Ainsi, après une détermination des valeurs de la conductivité hydraulique du bassin (Kf= 3,51.10-5 m/s) et du coefficient de proportionnalité empirique entre l'ouverture et la longueur des fractures (C= 0,0038), la carte des réseaux de linéaments, initialement réalisée dans l'environnement EASI/PACE de PCI, a pu être mieux exploitée. Les valeurs de perméabilités (Kmax et Kmini) induites par les fractures, ainsi que la moyenne (Kmax + Kmini/2) et les rapports de perméabilités (Kmax /Kmini); ainsi que les orientations λ_1 et λ_2 correspondantes,.ont alors été calculées à partir de la formule (Franciss, O., 1970):

$$\lambda(\max, \text{mini})) = \frac{1}{2}\ tg^{-1}\ \frac{2K_{NW}}{K_{WN}-K_{NN}}$$

et : $$K\left(\frac{\max}{\text{mini}}\right) = \frac{1}{2}(K_{WW} + K_{NN}) \pm \frac{1}{2}\sqrt{(K_{WW}-K_{NN})^2 + 4K^2_{NW}}$$

avec:

$K_{NN} = CL \cos^2 \lambda$
$K_{WW} = CL \sin^2 \lambda$
$K_{NW} = -CL\sin\lambda\cos\lambda$

PRINCIPAUX RESULTAS ET INTERPRETATION

• CARTE DE LINEAMENTS

La carte du relevé détaillé des linéaments comporte près de 16 000 segments assimilables à des fractures. Les linéaments ont été identifiés sur les images TM décrites plus haut, en exploitant les possibilités du système d'information géographique de PAMAP, qui permet l'affichage de compositions colorées et l'édition de fichiers vectoriels. Une carte présentant les linéaments d'importance régionale associés aux accidents majeurs dans le socle, a été préparée à l'aide principalement de la combinaison TM6+TM7 et des filtres directionnels de Sobel utilisant une matrice de 7 x 7. On a pu noter une très forte correspondance entre les traits géologiques dominants perçus sur les données TM et les discontinuités aéromagnétiques. Ceux-ci se répartissent selon les principales directions tectoniques d'Afrique: N170-190°, N80-100°, N30-60° et N120-160° (Figure 1).

• COULOIRS SOUTERRAINS DE CIRCULATION D'EAU ET AXES D'ALIMENTATION DU BASSIN

Dans le bassin, les valeurs de perméabilités induites calculées varient de 0,11 à $0{,}66.10^{-4}$ m/s (alors que les résultats des travaux antérieurs n'ont toujours fourni que des valeurs très faibles: 10^{-8} m/s), et sont de ce fait assez voisines des perméabilités réelles des terrains (Tableau 1). La nette amélioration obtenue dans cette méthode étant attribuable à la densité assez forte des fractures relevées en images satellitaires (62 en moyennne par 1,44 km^2) grâce à l'emploi des techniques de traitement numérique d'images et d'un système d'information hydrogéologique à référence spatiale (SIHRS).

L'étude des couloirs de circulation des eaux souterraines a été réalisée en superposant, dans un même plan, à l'intérieur du système d'information hydrogéologique à référence spatiale (SIHRS), la carte des variations spatiales des perméabilités induites et le réseau hydrogéographique. Ce travail fait ressortir une parfaite concordance entre le tracé des cours d'eau en surface et celui des différents axes de fortes perméabilités présentés plus haut (Figure 2).

Les deux fortes valeurs de perméabilités : 0,8722 et 0,8215 m/s correspondent l'une à la source de la Marahoué située à Kanyéné et l'autre à proximité de l'exutoire du fleuve situé en aval.

La Marahoué (cours d'eau principal du bassin) se superpose presque exactement à l'axe principal Nord-Sud de fortes perméabilités. Quant au Yarani son affluent, il coule essentiellement dans les axes de fortes perméabilités répartis sur la bordure occidentale.

Quant aux domaines de faibles perméabilités induites, ils correspondent respectivement à des chaines d'inselbergs du Nord-Ouest, du Sud et de la bordure Nord-Est du bassin.

Ainsi, entre Morondo et Dianra village, la modification observable dans le tracé de la Marahoué qui passe du NS à NW-SE, caractérise de façon assez nette la déviation subie par l'axe principal de fortes perméabilités induites dans ce secteur, qui n'est autre chose que la manifestation d'un grand couloir de cisaillement passant par Dianra et Niakaramadougou.

Ainsi, les quatre axes de fortes perméabilités induites constituent des zones d'alimentation souterraines en eau pour le bassin. Ces résultats démontrent clairement qu'il existe une étroite relation entre les écoulements superficiels et souterrains ; en particuler, le long des principaux axes de drainage que constituent les mégafractures dans le bassin.

CONCLUSION

Une interprétation géologique des images Landsat TM et des données du champ magnétique total à l'intérieur du système d'information à référence spatiale, a permis d'établir la carte des principaux axes structuraux du bassin versant de la Marahoué, indispenable à la détermination des perméabilités induites par les fractures dans le bassin.

A l'intérieur du SIHRS, les variations spatiales des valeurs de ces perméabilités induites montrent que:

-l'alimentation des aquifères, qui se fait à travers les axes de drainage bien devéloppés, est plus intense sur la bordure Ouest que dans la partie orientale du bassin;

-les accidents majeurs logent les principaux cours d'eau de la région; en particulier, le tracé de la Marahoué se superpose au principal axe de drainage des eaux souterraines d'orientation Nord-Sud; elle prend sa source dans une nappe importante où Kmax présente la plus forte valeur (0,8722 m/s) et aboutit à un bassin d'accumulation situé à Tonhoulé non loin de l'exutoire; où la deuxième plus grande valeur de Kmax atteind 0,8215 m/s).

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Tab 1: valeurs de perméabilités induites

N°CERCLE	A1	A2	Kmax	Kmini	Kmax+kmini/2	Kmax/kmini
H1	-69	21	1,89E-05	1,47E-05	1,68E-05	1,28
H2	84	-6	2,22E-05	1,63E-05	1,92E-05	1,37
H3	-89	1	2,02E-05	1,85E-05	1,84E-05	1,22
H4	1	-89	2,56E-05	1,82E-05	2,24E-05	1,46
H5	7	-83	2,06E-05	1,19E-05	1,62E-05	1,73
H6	-73	17	1,82E-05	1,44E-05	1,63E-05	1,26
H7	7	-83	1,96E-05	1,50E-05	1,73E-05	1,31
H8	42	-48	2,12E-05	1,95E-05	2,04E-05	1,09
H9	-10	80	3,18E-05	2,67E-05	2,93E-05	1,19
G1	-72	18	1,94E-05	1,73E-05	1,84E-05	1,12
G2	11	-79	2,15E-05	1,99E-05	2,07E-05	1,08
G3	40	-50	2,66E-05	1,78E-05	2,22E-05	1,49
G4	73	-17	2,35E-05	2,13E-05	2,24E-05	1,11
G5	-55	35	1,98E-05	1,65E-05	1,81E-05	1,2
G6	-23	67	2,52E-05	1,84E-05	2,18E-05	1,37
G7	58	32	3,55E-05	2,25E-05	2,90E-05	1,58
G8	-36	54	2,29E-05	1,88E-05	2,08E-05	1,22
G9	-72	18	2,85E-05	2,25E-05	2,55E-05	1,27
G10	-81	9	2,31E-05	1,65E-05	1,98E-05	1,4
G11	-20	70	2,16E-05	2,02E-05	2,09E-05	1,07
G13	10	-80	2,27E-05	1,98E-05	2,12E-05	1,15
F1	76	-14	1,89E-05	1,60E-05	1,64E-05	1,08
F2	29	-61	1,98E-05	1,40E-05	1,70E-05	1,41
F3	-61	29	8,22E-05	5,01E-05	6,61E-05	1,64
F4	-40	50	2,90E-05	2,67E-05	2,77E-05	1,11
F5	-31	59	2,63E-05	2,41E-05	2,52E-05	1,09
F6	89	-1	2,23E-05	1,88E-05	2,06E-05	1,18
F7	39	-51	2,03E-05	1,57E-05	1,80E-05	1,3
F8	-66	24	2,95E-05	2,44E-05	2,70E-05	1,21
F9	80	-10	2,71E-05	2,38E-05	2,55E-05	1,14
F10	-10	80	2,72E-05	1,53E-05	2,13E-05	1,78
F11	8	-82	1,99E-05	1,70E-05	1,85E-05	1,18
F12	81	-9	1,58E-05	1,29E-05	1,42E-05	1,21
F13	-6	84	2,28E-05	1,80E-05	2,04E-05	1,26
E1	-33	57	2,47E-05	1,57E-05	2,02E-05	1,57
E2	42	-48	2,11E-05	1,73E-05	1,92E-05	1,22
E3	-90	0	2,28E-05	1,86E-05	2,07E-05	1,22
E4	38	-52	2,80E-05	2,52E-05	2,66E-05	1,11
E5	-61	29	2,67E-05	2,19E-05	2,43E-05	1,22
E6	21	-69	2,81E-05	2,08E-05	2,44E-05	1,35
E7	-66	24	2,28E-05	1,41E-05	1,84E-05	1,62
E8	-83	7	2,45E-05	1,69E-05	2,07E-05	1,45
E9	-42	48	2,33E-05	1,87E-05	2,10E-05	1,24
E10	-69	21	1,90E-05	1,71E-05	1,80E-05	1,11
E11	-54	36	2,38E-05	1,74E-05	2,06E-05	1,36
E12	-77	13	2,03E-05	1,82E-05	1,93E-05	1,11
E13	-48	42	2,18E-05	1,40E-05	1,79E-05	1,56
D1	76	-14	1,88E-05	1,53E-05	1,70E-05	1,22
D2	67	-23	2,09E-05	1,89E-05	1,99E-05	1,1
D3	-73	17	2,21E-05	1,62E-05	1,92E-05	1,37
D4	15	-75	2,66E-05	2,22E-05	2,44E-05	1,2
D5	-88	4	3,09E-05	1,65E-05	2,37E-05	1,87

Tableau 1: Valeurs de perméabilités induites par les fractures affectant le socle dans le bassin versant de la Haute Marahoué (l'azimut de chaque fracture est comptépositivement vers l'Ouest et négativement vers l'Est)

Tab. 1: valeurs de perméabilités induites

D6	-6	-86	3,01E-05	1,67E-05	2,34E-05	1,8
D7	-6	84	1,80E-05	1,73E-05	1,77E-05	1,04
D8	-74	16	2,02E-05	1,62E-05	1,82E-05	1,25
D9	-65	25	1,65E-05	1,36E-05	1,50E-05	1,22
D10	-69	21	1,90E-05	1,71E-05	1,80E-05	1,11
D11	-20	70	2,66E-05	1,61E-05	2,15E-05	1,67
D12	-47	43	2,12E-05	1,81E-05	1,97E-05	1,17
D13	20	-70	1,92E-05	1,60E-05	1,76E-05	1,2
D14	10	-80	1,79E-05	1,47E-05	1,63E-05	1,22
D15	-49	41	8,72E-05	2,84E-05	5,78E-05	3,07
C2	-20	70	2,57E-05	1,89E-05	2,23E-05	1,36
C3	-25	65	1,89E-05	1,59E-05	1,74E-05	1,19
C4	-1	89	2,85E-05	2,58E-05	2,71E-05	1,1
C5	-10	80	2,88E-05	2,24E-05	2,56E-05	1,29
C6	64	-26	2,33E-05	1,89E-05	2,11E-05	1,24
C7	-61	29	2,74E-05	1,80E-05	2,27E-05	1,52
C8	66	-24	2,08E-05	1,48E-05	1,78E-05	1,4
C9	57	-33	1,83E-05	1,62E-05	1,73E-05	1,13
C10	54	-36	2,26E-05	1,49E-05	1,88E-05	1,51
C11	-4	86	1,82E-05	1,38E-05	1,60E-05	1,32
C12	-21	69	2,00E-05	1,50E-05	1,75E-05	1,33
C13	1	-89	2,08E-05	1,66E-05	1,87E-05	1,25
C14	3	-87	2,22E-05	1,40E-05	1,81E-05	1,59
C15	-34	56	1,34E-05	9,11E-06	1,13E-05	1,47
B2	-10	80	2,34E-05	1,76E-05	2,05E-05	1,33
B3	-70	20	2,06E-05	1,67E-05	1,86E-05	1,23
B4	-57	33	2,76E-05	2,65E-05	2,70E-05	1,04
B5	-28	62	2,59E-05	2,29E-05	2,43E-05	1,12
B6	34	-56	2,05E-05	2,00E-05	2,03E-05	1,03
B7	92	-8	2,66E-05	1,52E-05	2,09E-05	1,75
B8	23	-67	2,98E-05	2,03E-05	2,49E-05	1,45
B9	86	-4	2,13E-05	1,98E-05	2,05E-05	1,08
B10	-24	66	2,22E-05	1,52E-05	1,87E-05	1,46
B11	-71	19	2,19E-05	1,35E-05	1,75E-05	1,58
B12	2	-88	1,52E-05	1,10E-05	1,31E-05	1,38
B13	84	-6	1,88E-05	1,25E-05	1,56E-05	1,51
B14	-58	32	2,04E-05	1,40E-05	1,72E-05	1,46
B15	60	-30	1,30E-05	1,07E-05	1,19E-05	1,22
A4	22	-68	2,55E-05	2,09E-05	2,32E-05	1,22
A5	-88	4	2,33E-05	2,10E-05	2,21E-05	1,11
A6	11	-79	1,92E-05	1,45E-05	1,69E-05	1,32
A7	12	-78	2,29E-05	1,91E-05	2,10E-05	1,19
A8	-21	69	2,62E-05	1,24E-05	1,93E-05	2,12
A9	-60	30	1,72E-05	1,54E-05	1,63E-05	1,11
A10	71	19	1,95E-05	1,38E-05	1,67E-05	1,41
A11	-19	71	1,86E-05	1,73E-05	1,79E-05	1,08
A12	79	-11	1,55E-05	1,09E-05	1,32E-05	1,43
A13	-60	30	1,57E-05	1,07E-05	1,32E-05	1,47
A14	-61	29	1,83E-05	1,50E-05	1,66E-05	1,22
A15	-61	29	1,26E-05	9,07E-06	1,03E-05	1,39

Tableau 1: Valeurs de perméabilités induites par les fractures affectant le socle dans le bassin versant de la Haute Marahoué (l'azimut de chaque fracture est compté positivement vers l'Ouest et négativement vers l'Est)

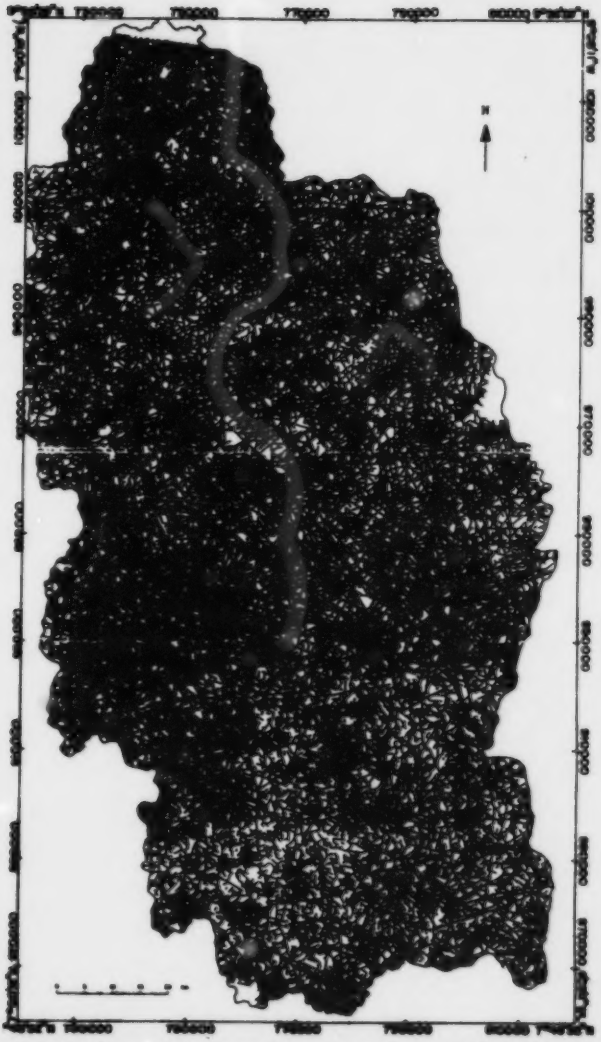

Figure 1: Carte des réseaux de linéaments du bassin versant de la Haute Marahoué, établie à l'aide des images de Landsat TM réhaussées et ineterprètées à l'intérieur du SIHRS

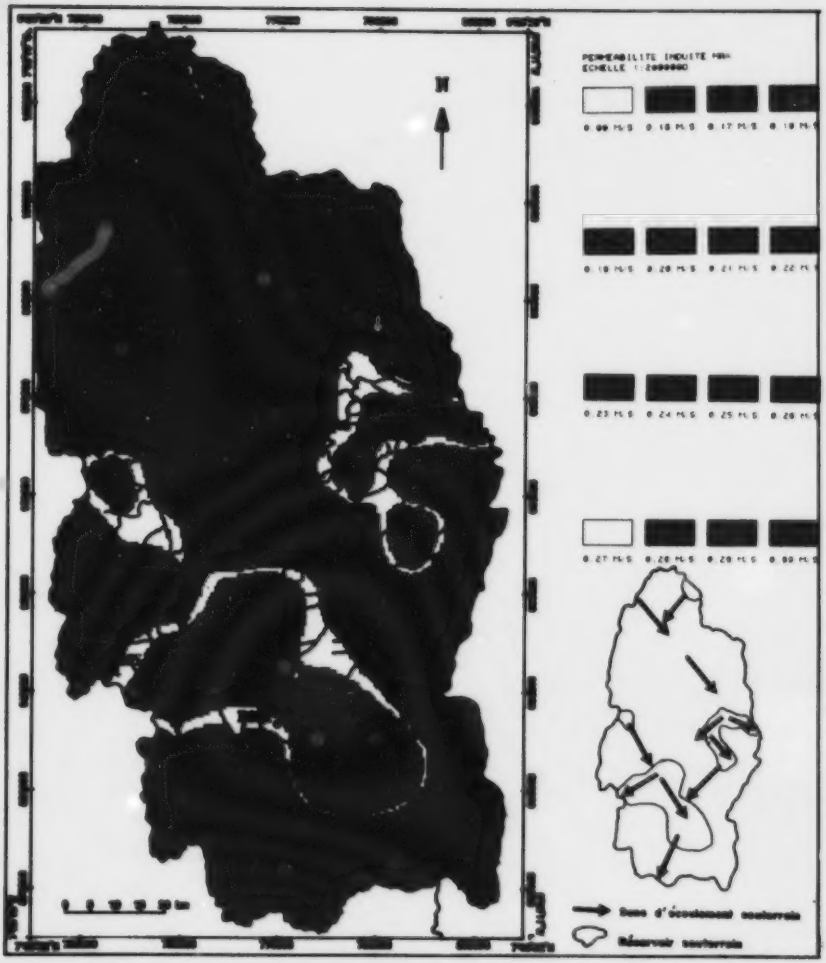

Figure 2: Couloirs souterrains de ciculation d'eau et axes préférenciels d'alimentation des nappes du bassin versant de la haute Marahoué, déterminés grâce à l'interprètation des perméabilités induites par les fractures à l'intérieur du SIHRS

APPLICATIONS OF REMOTE SENSING AND GIS IN THE MAPPING, EVALUATION AND MONITORING OF AGRICULTURAL RESOURCES IN NORTHWESTERN NIGERIA

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ABSTRACT

Agricultural land development in Nigeria is dominated by small holder subsistence farmers. Possibilities for improved and expanded agricultural production exist but such transformation is inhibited by the lack of spatial and temporal resource information. In recognition of this situation, a joint project between the University of Lagos and the University of Waterloo, funded by IDRC, was carried out to explore the capabilities of digital and visual analysis of Landsat MSS data for mapping and monitoring of agricultural resources of the Sokoto-Rima basin of northwestern Nigeria. While the result of this project demonstrated the capability of Landsat MSS for mapping and monitoring at regional scales, the detailed mapping and evaluation of the small-scale mixed farming being practiced in the floodplain (locally called Fadama) areas of the basin would require an integrated application of remote sensing and GIS.

Consequently, the second phase of the project is designed to explore the integration of remote sensing techniques and local knowledge systems using a Geographical Information System (GIS) approach. The goal of this project is to demonstrate the potential of these methodologies as a starting point for assembling the often ignored fundamental resource information for agricultural and rural development in Nigeria. This paper discusses the progress of this project.

BACKGROUND

In recognition of the potential of remotely sensed data and the prevailing inadequacy of basic resource information for planning purposes, a proposal was submitted in 1984 to the University of Lagos Central Research Committee for a national land use inventory project. Preliminary consultations on the project were held with a number of government agencies, particularly the River Basin Development Authorities.

A number of constraints dictated the selection of the Sokot-Rma Basin and methodology adopted for the study. They included:

* the size of Nigeria, its diverse ecological and land management practices;
* inadequacy of field mapping and other traditional resource inventory techniques;
* probability of obtaining cloud-free remote sensing images; and
* co-operation with an external institution that is willing to share its skills, instrumentation and other research materials for digital processing.

APPLICATIONS DE LA TÉLÉDÉTECTION ET DES SIG À LA CARTOGRAPHIE, L'ÉVALUATION ET LA SURVEILLANCE DES RESSOURCES AGRICOLES DANS LE NORD-OUEST DU NIGÉRIA

RÉSUMÉ

Au Nigéria, l'agriculture est surtout le fait de petits exploitants qui cultivent pour leur propre subsistance. Il existe des possibilités d'améliorer et d'accroître la production agricole mais une telle transformation est limitée par le manque de données spatiales et temporelles sur les ressources. Reconnaissant cette situation, l'Université de Lagos et l'Université de Waterloo ont entamé un projet conjoint, subventionné par le CRDI, afin d'explorer les capacités de l'analyse visuelle et numérique de données du scanneur multibande SMB Landsat pour la cartographie et la surveillance des ressources agricoles du bassin de la Sokoto-Rima dans le nord-ouest du Nigéria. Ce projet a permis de démontrer la capacité du SMB Landsat pour la cartographie et la surveillance à une échelle régionale mais la cartographie et l'évaluation détaillée de l'agriculture mixte à petite échelle, qui se pratique dans les portions inondables du bassin (ce qu'on appelle localement Fadama) nécessiteraient une application intégrée de la télédétection et des SIG.

Par conséquent, la deuxième phase du projet veut explorer l'intégration des techniques de télédétection et les systèmes d'information locaux au moyen d'un Système d'information géographique (SIG). L'objectif de ce projet est de démontrer le potentiel que présente ces méthodes comme point de départ pour assembler les données sur les ressources, souvent ignorées mais fondamentales au développement rural et agricole au Nigéria. Le présent article donne une idée de l'état d'avancement du projet.

These considerations resulted in the joint project between the Departments of Geography at the Universities of Lagos (Nigeria) and Waterloo (Canada). It started in August 1985 and was funded by IDRC, Canada.

THE SOKOTO-RIMA BASIN

The Sokoto-Rima basin in northwestern Nigeria was selected (Fig.1). It covered an area of about 200,000 square kilometers. The area is characterised by both wide floodplains (locally called Fadama); "Sokoto plains" consisting mainly of sedimentary rocks with scattered lateritic capped hills and the high plains consisting of highly dissected Basement Complex rocks. Its climate is semi-arid with long severe dry season (October to May-June) and short wet season that lasts for only about four months. Rainfall varies spatially and temporally while potential evapotranspiration, is negative in most months since the past five decades.

Subsistence agriculture by sedentary Hausas and uncontrolled grazing by normadic Fulanis are the predominant occupation in the basin. Cultivation is carried out within the sandy upland areas (locally called Tudu land) and in the fadama land. While the tudu land is cultivated only during the short wet season, the fadama land is "normally" cultivated during both dry and wet seasons. Intercropping is widespread on the highly fragmented and uneconomically small farm holdings (usually less than one hectare). To reduce total crop failure arising from unpredictable rainfall regime, farmers in the study area have several farm plots (ranging from 1-12) and they typically include a mixture of both fadama and tudu lands. As a result of increasing consumption of the natural vegetation for various domestic purposes and uncontrolled grazing, marginal vegetation of short grazes and shrubs predominate in the area. Consequently, the rapid population growth and the resource management practices have presented a great threat to the viability of future agricultural operations in the basin.

To improve agricultural production in the basin, large-scale river-valley dams and reservoirs were constructed on Rivers Sokoto at Bakolori and Rima at Keita village near Goronyo in 1978/79 and 1984 respectively. In spite of the good intentions of these programmes the lack of integrated resource information has led to unintentional negative results.

PHASE I OF THE PROJECT

RATIONALE AND PROCEDURE FOR THE APPLICATION OF SATELLITE REMOTE SENSING

This phase of the project was an attempt at understanding the impact of both natural and human-induced changes and how to prudently plan and manage the marginal land resources of the basin. Efforts were mainly tailored to:

- determine the best procedures for identification, mapping and monitoring resource features in the area from remote sensing data with a bias towards agriculture;
- develop procedures for monitoring changes in agricultural practices using digital and visual analysis of landsat (MSS) data;

* provide practical results that could be used by relevant government planning agencies in Nigeria for further development of agricultural resources of the area.

To meet these objectives, the first task was the identification of all the available remote sensing imageries and other documentary information that could be used. Up-to-date topographic and thematic maps are a rarity in Nigeria. To fly aerial photography for mapping the area would involve considerable time and cost. Hence the need to explore the advantages of satellite remote sensing data.

Based on available resources and time for the project, it was not possible to map the whole basin. Seven contiguous areas covering a total of about 20,000 sq.km. were selected and delineated for the project. Available dry and wet seasons Landsat MSS imagery of December 1984 and July/August 1986 were acquired for the project. In addition, Landsat MSS imagery covering the two dam sites and recorded on December 7, 1975 (i.e. before they were constructed) was also acquired. For experimental purposes, the higher resolution Landsat TM and SPOT imagery were acquired for an area centered on the city of Sokoto.

Computer compatible tapes (CCTs) and the positive films of the data were acquired. The CCTs were used for digital analysis on the Dipix ARIES III image analysis system in the Faculty of Environmental Studies at the University of Waterloo. Visual analysis was carried out using the transparencies on a PROCOM 2 projection system in the Department of Geography at the University of Lagos. In the process of carrying out the project several image interpretation techniques including change detection techniques were examined.

SUMMARY OF RESULTS FOR PHASE I

Details of the procedures and findings of the project have been published in several technical proceedings and journals (Bullock and Adeniyi, 1992). Having been subjected to centuries of unplanned exploitation, the area has been highly degraded. Recent human intervention through the construction of large river-valley dams and reservoirs has not substantially improved the situation. Instead, it has led to unintentional loss of productive agricultural land, while soil erosion and destruction of the natural vegetation have continued unabated. Consequently, the social and economic situation have largely remained unchanged.

This phase of the project demonstrated that:

* fadama lands are a highly significant resource whose importance require more detailed resources information for sustainable agricultural development;

* significant changes have taken place in the area as a result of natural and human activities;

* these changes are more pronounced within the fadama than the tudu land;

* maximum likelihood classification technique was found to be adequate for rapid accumulation of thematic information at a regional scale;

- relatively more information can be obtained from visual analysis of enhanced satellite imageries when used in association with digital technique;

- the low resolution (Landsat MSS) imagery is only suitable for mapping at regional scale; and

- high resolution (SPOT HRV or Landsat TM) would be required for a more detailed mapping of the area.

At the end of the phase I, it was concluded that more research efforts should be directed at the acquisition of information on the various components of the Land Management Systems in the basin. The following conclusions were drawn:

(i) that further remote sensing applications in the area should be based on the use of imagery with high spatial resolution;

(ii) that further socio-economic data on institutional and local knowledge system should be collected and integrated with remote sensing data in order to assist in the development of operational land use plans and appropriate monitoring strategy;

(iii) that an efficient field operation should be developed for the area as reliance on the old topographic maps may be misleading; and

(iv) that proper integration of resources data and future monitoring activities reqire the application of Geographic Information Systems (GIS).

It was against these conclusions and the comments of the participants at the post-project works conducted both in Lagos and Sokoto that the second phase of the project titled "Local-Level Mapping" was based.

PHASE II OF THE PROJECT

SCOPE AND OBJECTIVE

Rural development is now viewed as the foundation for National Development in Nigeria. The most pressing immediate need for its achievement is an adequate survey of agricultural and related resources at the local level. Hence the second phase has been designed on a methodological framework based on the integration of remote sensing techniques and local knowledge systems using a GIS approach. In doing so, the officials of the local agencies such as the State Ministry of Agriculture, the Sokoto Agricultural Development Authority, the Sokoto-Rima Development Authority, the State Ministry of Water Resources as well as the officials of the Local Governemnts within the project area have been engaged at the field level.

Unlike in the first phase, the area covered in this phase is only 60km by 60km, that is, one SPOT scene. The area selected is centred on Sokoto town, about 100 to 125km downstream of the Goronyo and Bakolori dams. It therefore covers a reasonable proportion of the floodplain

areas of Sokoto, Rima and Sokoto-Rima Rivers.

The specific objectives include:

(i) to identify the dynamics of land management in a selected number of Local Government Areas (LGAs) of the Sokoto-Rima Basin with special emphasis on its floodplain portion;

(ii) to develop and test the application of hybrid remote sensing techniques based on digital processing and visual analysis of SPOT data for the identification of seasonal changes in landuse and landcover in the selected area;

(iii) to demonstrate the application of GIS techniques in the integration and analysis of remote sensing data and local knowledge systems;

(iv) to examine institutional arrangements for land and water management in the area, with particular attention to the impact of such arrangements on local agricultural practices;

(v) to demonstrate the efficacy of this methodology as a starting point for assembling information for rural development;

(vi) to provide additional training for Nigerian personnel in remote sensing and GIS technologies and to increase the capabilities of the Department of Geography at the University of Lagos in their use; and

(vii) to disseminate the project results to national, state and local planning authorities, demonstrate to them the potential of remote sensing and GIS technologies and also to contribute to the overall goal of national development in Nigeria.

PROCEDURE

To meet the objectives specified above, five major components have been identified. They are remote sensing, physical environment characteristics, local knowledge system, institutional arrangements, and GIS. The way these are related as shown on figure 2 is presented under these headings.

Remote Sensing Component

The remote sensing aspect of this phase is designed to explore the suitability of high resolution SPOT satellite system for the analysis of agricultural and other land uses in the fadama land. SPOT multispectral and panchromatic dry and wet seasons data acquired during February/March and August/September respectively. Since data at this resolution are less suitable for digital mapping using current universal classification algorithms, the project was designed for hybrid analysis. This component is to be used for:

(i) Identification of uncultivated land and its characteristics;

(ii) Identification of the physical attributes of the Fadama land with respect to hydrology and geomorphology and soils;

(iii) Identification of crops/crop mixes;

(iv) Identification of the seasonal changes in the above elements;

(v) Settlements and physical infrastructures; and

(vi) Integration of derived information into GIS.

Physical Component

Basic physical data is required for the assessment of land capability. These will include climatic conditions during the two cropping periods, landform units and associated soils, land use types; soil conditions as they relate to crop growth, land damage and land loss resulting from sheet and channel erosion, inundation and the presence of duricrusts.

Available data on the above elements and those to be extracted from remote sensing data were to be complemented by direct field obseration, measurement and laboratory analyses. Both recording and non-recording rain guages have been installed and local officials under close supervision have been assigned to monitor them. Also, soil survey through spatial sampling have been selected to sere as base-line information for the principal soils recognised in the local knowledge system. Samples collected are currently been subjected to physical and chemical analysis.

Local Knowledge System Component

Those aspects of the local knowledge system relevant to the management of land resources are being identified. Field surveys and interviews on the local knowledge systems are being undertaken with a view to identifying:

(i) the local perception of land capability, the criteria on which it is based and the land use consequences of the application of this information base;

(ii) the spatial distribution of land types recognised by the local knowledge system;

(iii) the perception of, and reaction to environmental change.

Institutional Arrangement Component

This component has been included in light of the conviction developed during the first phase that some of the problems of the area relate to the institutional framework surrounding present water and land management practices. Data are being collected regarding the following topics which encourage or discourage water management in the context of rural deelopment:

(i) existing policies;

(ii) leverage points - legitimization, functions, structures, processes and organizational structure;

(iii) perceived capability of existing and possible alternative institutional arrangements; and

(iv) possible modifications to institutional arrangements.

GIS Component

GIS is planned to be used for the integration and modelling of the data collected by the various other components. of the project. Overlays produced from all these data will be integrated to produce a land capability map for the local government areas within the project area using GIS. Results expected from the component include:

* Spatial and temporal delineations of the fadama lands being permanently cultivated; cultivated only during the dry season; cultivated only during the wet season and not cultivated at all.

* Determination of the suitability of the land type for specific crops.

* Determination of the economic size farm holding on different land types.

* Assessment of the impact of the existing uses based on the local knowledge systems and institutional arrangements.

* Provision of single and composite thematic maps for the use of the local authorities.

PRELIMINARY REPORT

Acquisition of equipment and materials:

The first project year was spent on the acquisition of equipment and materials for the project. These include digital tablet, PC computer with 80386 Chip (IBM PS/2 model 70), hard disk (115 MGB), monochrome and XVGA colour monitor, Tydac Spatial Analysis Systems (SPANS), hydro and soil equipments, and a four-wheel vehicle. All these were acquired in Canada and USA and shipped to Lagos. Custom clearance delayed the installation of the equipment.

The 1990 wet season SPOT (XS, P) digital tape was acquired, processed and converted to enhance transparent positive films for visual interpretation. The progress made so far especially with respect to the remote sensing component is discussed below.

Digital Image Processing:

Following the conclusion arrived at during the first phase of this project, the analysis of RS data

is based on a hybrid approach. In this context, digital processing is only employed for geometric correction and image enhancement of the 1990 data. This resulted in the generation of enhanced positive transparent films for visual image interpretation.

Up-to-date maps showing sufficient and uniformly distributed ground control points (GCPs) are required for carrying out geometric corrections on remote sensing images. For the study area, the available 1:100,000 topographic maps are over 25 years old. Thus only 12 and 14 GCPs could be used to carry out the second order polynomial transformation for the SPOT XS and P images respectively. This was improved for visual analysis with the use of cubic convolution algorithm. With topographic maps of scale 1:50,000 that later became aailable, the XS image was resampled to 10 meters and combined with P mode through image to image registration based on first order polynomial transformation. The resultant combined XS/P data was geometrically corrected using 25 GCPs.

Various image enhancement techniques were examined in order to produce images that would facilitate the extraction of all the desirable information. Based on our experience, Vegetation Index (VI) on SPOT (XS) was not as good as the enhanced colour composite. A high pass edge enhancement was first performed on the geometrically corrected panchromatic data using PCI EASI/PACE Software. For the XS/P data, a 5 by 5 edge enhancement filter was applied to the image. The result was subtracted from the original panchromatic image and enhanced using a piecewise linear stretch.

All the data sets were each created into four overlapping sub- areas. Those on XS and P data were created a scale of 1:200,000 while those on the integrated (XS/P) at a scale of 1:100,000 were created covering essentially the fadama areas. All the data were converted to positive transparencies on the FIRE 240 Colour Imaging Recorder, located at the Canada Centre for Remote Sensing (CCRS), Ottawa.

Visual Image Interpretation:

PROCOM-2 equipment is being used for the interpretation on which it is not difficult to interchange the different data set during the period of interpretation. Preliminary interpretation has been carried out using all the three data sets. As a first step in the interpretation, the sub-areas were divided into land types. Interpretation was then carried out within each land type. Although, the final classification scheme has not been conclusively drawn up as the dry season SPOT data is currently been interpreted, the relative interpretability of the three data sets for specific resource features has been found and documented. These include spatial location and extent of cultivated and uncultivated lands, settlements, physical infrastructure, surface hydrology, vegetal distribution and crop mixes. Digital sample maps of some of these componenets for a sub-section of the project area are shown on figs. 3 through 5.

Fieldwork:

Prior to the interpretation of the data set, a fieldwork was conducted in August, 1990 at about the time of acquisition of the SPOT data. The cropping patterns were examined and documented on topographic maps. Also, the areas where hydro and soil equipment would be installed were

identified.

The preliminary derived maps were again taken to the field in July/August 1991 for systematic field checking. The high resolution and capability of each data set in mapping each class of resource feature and the accuracy of the generated maps were found to be highly reliable. Except for inability to identify individual crops and variations in the boundary of some features which are normally expected in such a complex environment, the results obtained are very satisfactory. The success can be attributed to the high resolution of the data sets, capability of each of them in mapping different resource features and initial fieldwork carried out at the time of the image acquisition.

Physical Measurements

Already, maps on soil types (fig. 6), slope and topography have been compiled. Some soil samples have been collected through burrowed pits for the wet season and are currently under laboratory analysis. Elements being determined include soil texture, colour, permeability, infiltration bulk density, depth, infiltration, groundwater depth, alkalinity and chemical (potassium, phospates and nitrogen) content.

Hydrological information on water releases by dam and other reservoir stream gauges and flows have been collected from existing stations and stored on the PC. In addition, supplementary data from established gauging stations are currently been collected from the field for GIS analysis. Also are those of climatic elements especially rainfall, temperature, wind, humidity and evapotranspiration.

Local knowledge system and institutional arrangement

Field observation, field interiews and relevant existing literature have been used to collect data on the perception and reaction of the local subsistence farmers. Administrators have also been interviewed on existing policies, their activities and hinderances relative to the development of agricultural resources of the area under focus. To suppliment information already collected, a set of questionnaire has been designed to be administered to both the farmers, employees and employers of all institutions and parastatals in the region especially the agriculturally related ones. They include environmental protection, rural and community development agencies and associations in addition to those listed above.

GIS Applications

The full application of the GIS can only start after the interpretation of remote sensing data set and completion of data collection from other sources. However, GIS activities that has been carried out are: the inventory of data availability; documentation of data accuracies, lineage and usefulness of the data sets to the objectives of this project, preparation of the available data for the digitization process and the generation of some maps as shown on Figures 3 through 6. To speed up the digitization process, four final-year undergraduate students are currently being trained.

Potential Results Envisaged

One of the envisaged products of the local level mapping project is the generation of land suitability classes. Detailed seasonal landuse maps for the selected section of the floodplain will also be available, as will various thematic maps. With the integration of other information from the enumerated research components, the project will provide a credible basis for making recommendations regarding how existing land and water management practices might be modified for more consolidated and sustainable cropping pattern.

CONCLUSION

The economic status of every nation, and in particular, development of its rural community is almost always a direct function of the efficiency of the use of its available natural resources. Problems emanating from poor decisions on their allocation and use can contribute to rapid declines in resource quantity, quality and economic productivity. Althouth the causes of the problems are many and complex, the most fundamental and the least attended to in Nigeria is low level of technological applications to develop her "abundant" agricultural resources. It is therefore suggested that if Nigeria's land resource base, given its rapidly growing population and changing environment is to meet the basic demands for food and forestry production, housing, transportation, energy development and rural industrial growth, it is vital that comprehensive information on environmental and land resources should be collected, organised and constantly updated so that all citizens and levels of governments can be guided as to the most beneficial policies on agricultural and rural development.

Although remote sensing and its related technologies have revolutionalised the generation of resources information, and those nations that have employed them have greatly improved the planning, management and development of their natural resources, Nigeria is yet to give priority to the development and application of the technology. Yet, experience has shown that the opportunities afforded by these technologies can be obtained through committed experimental research activities.

In other words, the beneficial application of the technology depends largely on a number of enabling resources such as skilled manpower, availability of imagery and imagery interpretation equipment, local educational and research institutes and more importantly, supportive local institutions (Bartolucci, et al, 1980). There is therefore a need for an action oriented research in the application of remote sensing in Nigeria in line with the on-going research reported in this paper.

Acknowledgements

The authors are pleased to acknowledge the financial support from the Information Sciences Division of the International Development Research Centre (IDRC), Ottawa. Support from the Central Research Committee of the University of Lagos and the Faculty of Environmental Studies at the University of Waterloo is also appreciated. We also Acknowledge the support of the Sokoto State Government and their various agencies.

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BULLOCK, R.A. and ADENIYI, P.O. (eds) (1992) Remote Sensing of Agricultural Resources in Northwest Nigeria. Waterloo, Department of Geography Publication No.32.

Fig I: THE STUDY AREA

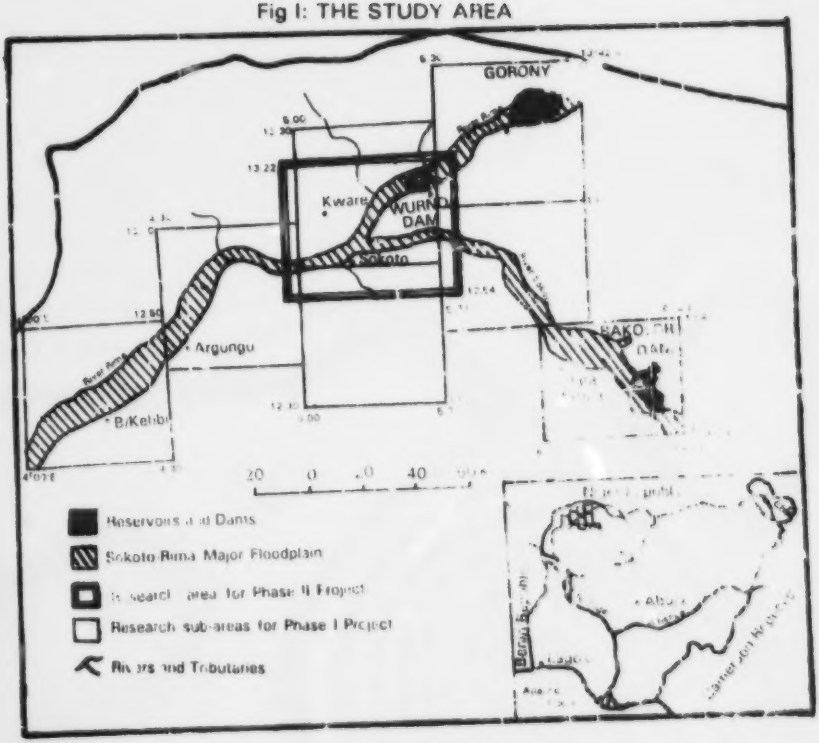
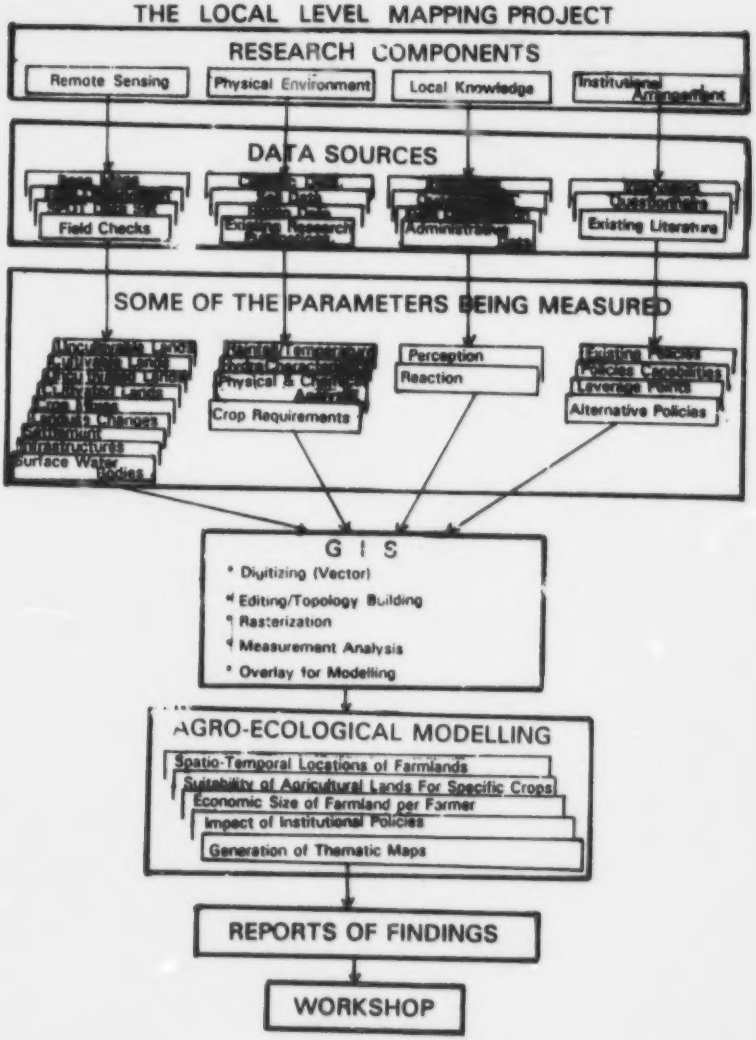
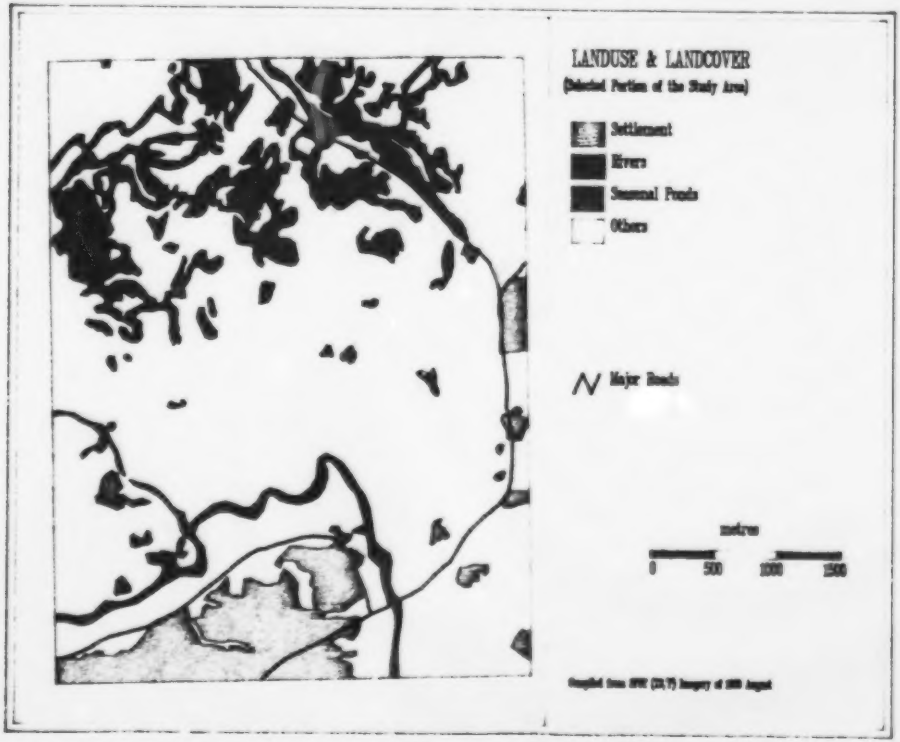
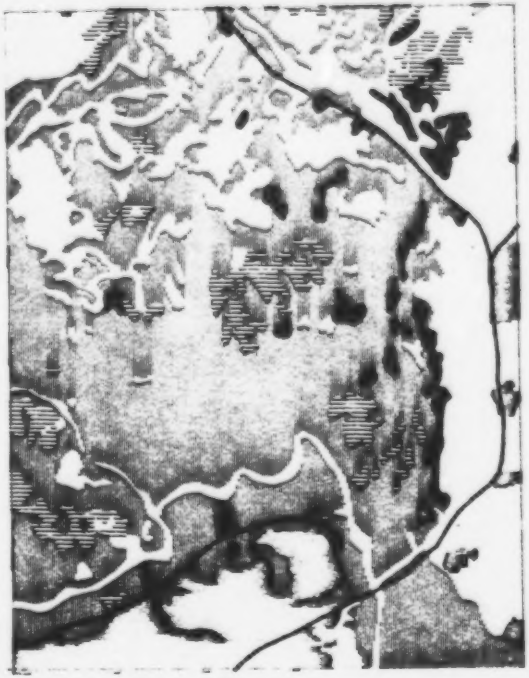


FIG 2: METHODOLOGICAL FRAMEWORK OF THE LOCAL LEVEL MAPPING PROJECT




LANDUSE & LANDCOVER
(Selected Portion of the Study Area)
Settlement
Rivers
Seasonal Ponds
Others
Major Roads
metres
0
500
1000
1500



LANDUSE & LANDCOVER

(Selected Portion of the Study Area)

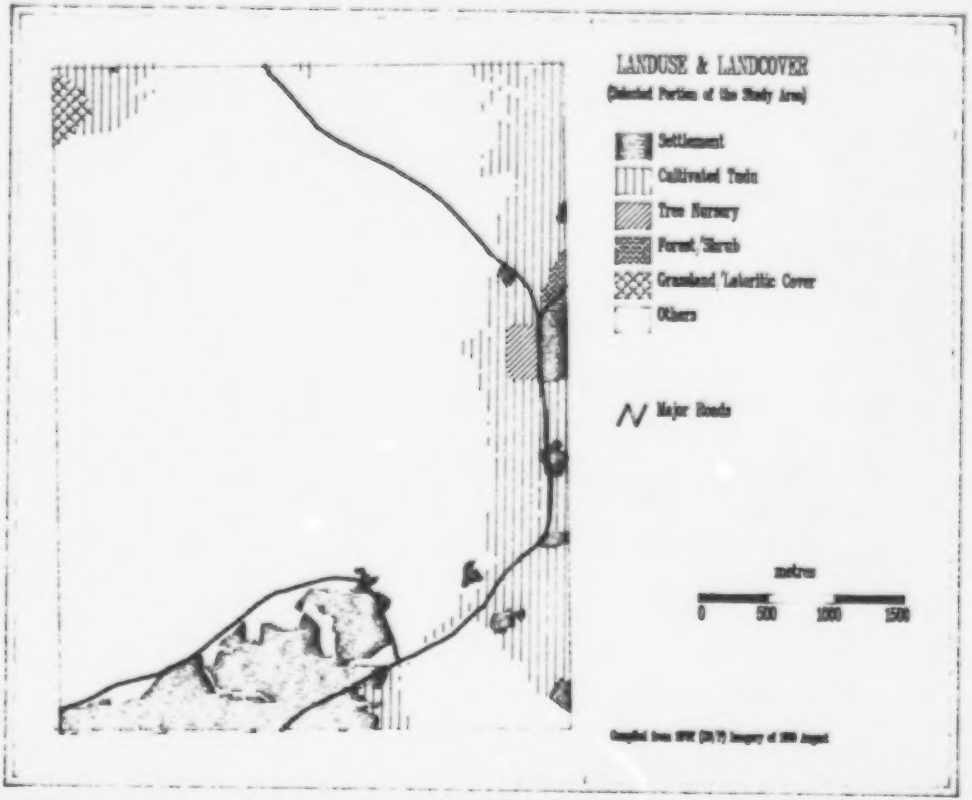
- Settlement
- Cultivated Paddocks
- Vegetated Wetlands
- Orchards
- Unvegetated Wetlands(mudflats)
- Others

Major Roads

metres

0 500 1000 1500

Compiled from SPOT (XS) Imagery of 1988 August


LANDUSE & LANDCOVER
(Selected Portion of the Study Area)
Settlement
Cultivated Tools
Tree Nursery
Forest, Shrub
Grassland, Lateritic Cover
Others
Major Roads
metres
0
500
1000
1500

SITE SELECTION FOR BRACKISHWATER AQUACULTURE DEVELOPMENT AND MANGROVE REFORESTATION IN LINGAYEN GULF, PHILIPPINES USING GEOGRAPHIC INFORMATION SYSTEM[1]

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Abstract

Brackishwater aquaculture production in Lingayen Gulf in northwestern Luzon, Philippines, is one of the highest in the country. Most of the aquafarms are mangrove forest and marginal lands which have been converted for milkfish and shrimp culture. Brackishwater aquaculture development has been closely associated with mangrove forest denudation. In recent years, the ecological importance of mangrove forests has been recognized, especially as nursing and feeding grounds for many aquatic species. This has led to efforts in mangrove reforestation and conservation.

Are there potential sites for brackishwater aquaculture expansion in the Lingayen Gulf? A site selection study using geographic information systems (GIS) identified about 16,000 ha of potential sites that excluded major agricultural land uses and mangrove reforestation areas. For mangrove reforestation, about 12,000 ha have been identified. The results of this study are as yet preliminary and further work is needed to determine the actual potential sites.

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1 ICLARM Contribution No. 784.

RECHERCHE DE SITES POUR L'AMENAGEMENT AQUACOLE EN EAU SAUMATRE ET POUR LE REBOISEMENT DES MANGROVES DANS LE GOLF LINGAYEN, PHILIPPINES A L'AIDE DES SYSTEMES D'INFORMATIONS GEOGRAPHIQUES

Résumé

La production aquacole dans les eaux saumâtres du Golf Lingayen, au Nord-Ouest de l'île de Luçon, Philippines, est l'une des plus importantes du pays. La plupart des fermes aquacoles sont établies dans des forêts de mangroves et sur des terres marginales converties pour l'élevage des chanidés et de la crevette. Ces dernières années toutefois, des terres agricoles (rizières) ont également été converties pour l'élevage de la crevette.

Le développement de l'aquaculture en eau saumâtre est étroitement lié au déboisement des mangroves. Depuis quelques années, on reconnait l'importance écologique de ces forêts, notamment comme aires de reproduction et de nourrissage de nombreuses espèces aquatiques. Cette prise de conscience a mené à ce que des efforts soient réalisés dans le sens du reboisement et de la conservation.

Existe-t-il des sites propices à l'expansion de l'aquaculture en eau saumâtre dans le Golf Lingayen ? Une étude sur la recherche de sites réalisée à l'aide du système d'information géographique (GIS) a révélé l'existence d'environ 16.000 ha de sites potentiels, exception faite des grandes terres agricoles et les sites de reboisement des mangroves. Les données sur les types de sols, la physiographie, l'occupation des sols, etc. ont été évaluées au l'aide du GIS pour choisir les sites de reboisement des mangroves. Environ 12.000 de ces sites ont été identifiés.

Les résultats de cette étude ne sont qu'au stade préliminaire. Des vérifications et l'évaluation sur le terrain des terres non agricoles existantes sont nécessaires pour déterminer les sites potentiels réels où il est possible de développer l'aquaculture en eau saumâtre et de mettre en oeuvre des projets de reboisement de mangroves.

1. INTRODUCTION

The Lingayen Gulf area, located in northwestern Luzon, Philippines, covers the provinces of Pangasinan and La Union (Fig.1). It is one of the top fisheries producers in the country. Brackishwater aquaculture production, mainly milkfish (*Chanos chanos*) and penaeid shrimps contribute about 11% of the national aquaculture production while marine fish landing is about 26%. Most of the fishfarms are converted mangrove forest and marginal lands and recently, some agricultural lands (e.g., ricelands).

Brackishwater aquaculture development has been closely associated with mangrove denudation. The remaining mangrove stands are mostly found along the periphery of fishponds, especially in Pangasinan. In recent years, the ecological importance of mangrove forests has been recognized by the government, especially as nursing and feeding grounds for many aquatic species. As a result, the Department of Environment and Natural Resources (DENR) through its regional office are implementing mangrove reforestation projects in the two provinces.

This preliminary study is part of the development of an integrated coastal area management plan for Lingayen Gulf (ICAMPLG) under the ASEAN/US Coastal Resources Management Project. One of the recommendations of the plan is a zonation scheme for land use and coastal water use such as for artisanal fishing, marine parks, aquaculture (brackishwater and marine), mangrove reforestation, artificial reefs and agriculture, etc. This zonation scheme will be developed as part of the 2-year GIS Coastal Area Management and Planning Project (GISCAMP) funded by the International Development Research Centre of Canada (IDRC).

2. MATERIALS AND METHODS

Site selection criteria for brackishwater aquaculture, especially for Southeast Asia are based on various works [e.g., Menasveta, 1982; Hechanova, 1982; Khoo and Wuan, 1982; Adisukresno, 1982; Poernomo 1990]. The procedure used in this study, however, is based on spatial data using a GIS software called SPANS. Table 1 summarizes the criteria used in site selection for brackishwater ponds.

Digitized thematic maps such as physiography, soil texture, etc. are at 1:100,000 scale while topographic maps are at 1:50,000 scale. For elevation, spot height and the 10-m contour lines were digitized from topographic maps. Elevations between 0 and 10 m were derived from information on physiography (e.g., along tidal flats and beaches). These are interpolated using a Triangulated Irregular Network (TIN). For fishponds and existing mangrove areas, information was extracted from 1989 Landsat TM data using MICROBRIAN and imported to SPANS as raster files.

Mangrove reforestation criteria are based on the guidelines set by the National Mangrove Committee of the Philippines and biogeographical studies on Philippine mangroves [Cadiz, 1987; Zamora 1989; TS-PNMC, 1986; Melana, 1987]. Table 2 gives a summary of the major parameters used in site selection for mangrove reforestation. In general, a buffer zone of 40-m wide mangrove forest should be maintained along river embankments and a 100-m belt facing the sea for coastal protection (or a minimum of 20 m). Cutting of mangroves even in areas where there are fishponds is prohibited. Instead, fishpond lessees are required to plant or maintain mangrove trees within their jurisdiction. Those given permit to cut mangroves (e.g., commercial timber) are also required to conduct silvicultural activities. Recently, activities (e.g., agriculture, timber cutting) in public lands with mangrove forest and in forest reserve areas have been prohibited.

In determining the potential sites for brackishwater aquaculture, a series of thematic maps were overlayed based on the criteria in Table 1. Likewise, similar procedure was used for potential mangrove reforestation sites but based on Table 2. From the recommendations of the ICAMPLG, milkfish culture should be geared towards intensification rather than expansion. At the same time, efforts should be directed to mangrove reforestation, especially along productive fry grounds, periphery of fishponds and certain coastlines. As such, a cross tabulation of the potential areas for brackishwater aquaculture and mangrove reforestation resulted in allocation of some areas in the former for reforestation purposes.

3. RESULTS AND DISCUSSION

Preliminary analysis using GIS showed an aggregate total potential brackishwater aquaculture areas of about 35,699 ha (Table 3; Fig. 2). The procedure used matches closely the site selection criteria in Table 1. In a separate analysis, result showed that 66% (10,400 ha) of the total area for fishponds and mangroves fall within the first 3 categories. About 22,252 ha met most of the criteria listed in Table 1. In terms of approximity to water sources, all areas categorized as excellent fall within 3 km from the seashore and rivers while for the good category, 65% and 57% fall within 3 km from the river and seashore, respectively.

In view of the recommendations of ICAMPLG regarding mangrove rehabilitation, some of the potential aquaculture areas have been earmarked for mangrove reforestation thereby reducing the overall extent of the former. Table 3 also shows the adjusted values.

Although there are a number of parameters listed in Table 1, not all thematic maps were used. For example, the erosion and slope maps are not necessary if an elevation map is available. At times, the use erosion and slope maps can exaggerate areal extent of potential sites, especially if the slope is flat but elevation is above the ideal tidal range. One difficulty encountered is on the accuracy of the thematic maps. Since these are produced elsewhere (e.g., Bureau of Soils and Water Management) with insufficient background information, we attempted minor corrections where some "ground truth" information is available.

The aggregate total potential area for brackishwater aquaculture has been substantially reduced as a result of reallocation for mangrove reforestation. It is expected that this be further reduced once additional information, especially through field verification, are available. For example, spatial distribution of tourist resorts is not available. Some of the potential sites fall within tourist resorts but the areal extent is not known by this study. Another example is on the settlements. The topographic maps used are more than 10 years old and there has been considerable settlement expansion not to mention changes in the coastline due to the July 1990 earthquake. Thus, updated information through Landsat imagery and aerial photos will be needed in order to establish the actual aquaculture potential sites.

The brackishwater aquaculture practice (milkfish culture) in Lingayen Gulf area is largely traditional characterized by poor farm inputs (low stocking density, use of natural food, poor farm management) resulting in low yield (1,000 kg/ha as against 2,000 kg/ha elsewhere). Thus, it is clear that aquaculture development should gear towards intensification rather than expansion. In contrast to milkfish culture, farm size for shrimp culture is generally small (< 5 ha) but operating at a semi-intensive level (i.e., high stocking density with supplemental feeding and aeration). How would the result of this study be useful in the context of brackishwater aquaculture development? Recently, ricelands and some agricultural lands have been converted to shrimp farming. This will clearly reduce the area for staple food production. The identification of potential sites, therefore, can discourage the conversion of agricultural lands to aquaculture, especially for shrimp culture.

Mangrove potential sites have an aggregate total of 19,515 ha, of which 12,678 ha is suitable (Table 4; Fig. 3). The values are the result of the adjustment made on the brackishwater aquaculture potential sites mentioned earlier.

There are only three categories used in mangrove site selection based on Table 2. These are suitable (meet all criteria), less suitable (does not meet some of the criteria) and not suitable. The above results need field verification to establish the actual potential areas similar to that for brackishwater aquaculture. Although the result is preliminary, the procedure used in this study has demonstrated that the areal extent for mangrove reforestation is wider than previously assumed, at nearly 20 times the ongoing projects. Even after field verification, the area may still be substantial.

The procedure used in this study is based on biogeographical parameters, mostly spatial while those used for ongoing projects lack such an approach (i.e., the implementing agency resorted to interviewing old folks whether an area was formerly with mangroves). The mangrove cover in the Lingayen Gulf area is patchy. Based on the 1950s topographic maps, about 50% of the mangroves areas had been converted to fishponds for the past 40 years. This could mean that most of the mangroves had already been logged prior to the Second World War.

Lingayen Gulf is a very productive fishing and fry grounds. The ecological importance of mangroves in fisheries provided the reason for conservation. The lack of proper technique in site selection, insufficiently trained staff and budgetary constraints have contributed to the slow implementation of mangrove reforestation projects. The standardization of site selection procedure for mangrove reforestation using GIS can be a step towards accelerating the implementation of such projects.

4. CONCLUSION

The use of GIS in selecting sites for brackishwater aquaculture and mangrove reforestation has been demonstrated in this study. Ground truthing including verification of the accuracy of thematic information is necessary in order to standardize the procedure and provide statistically valid results. Minor attempt has been made in this study but it remains an important issue. It is expected that the 2-year GISCAMP project will resolve this and other issues such as updating of land use patterns, establishing a GIS databank on the coastal resources and zoning.

5. ACKNOWLEDGEMENTS

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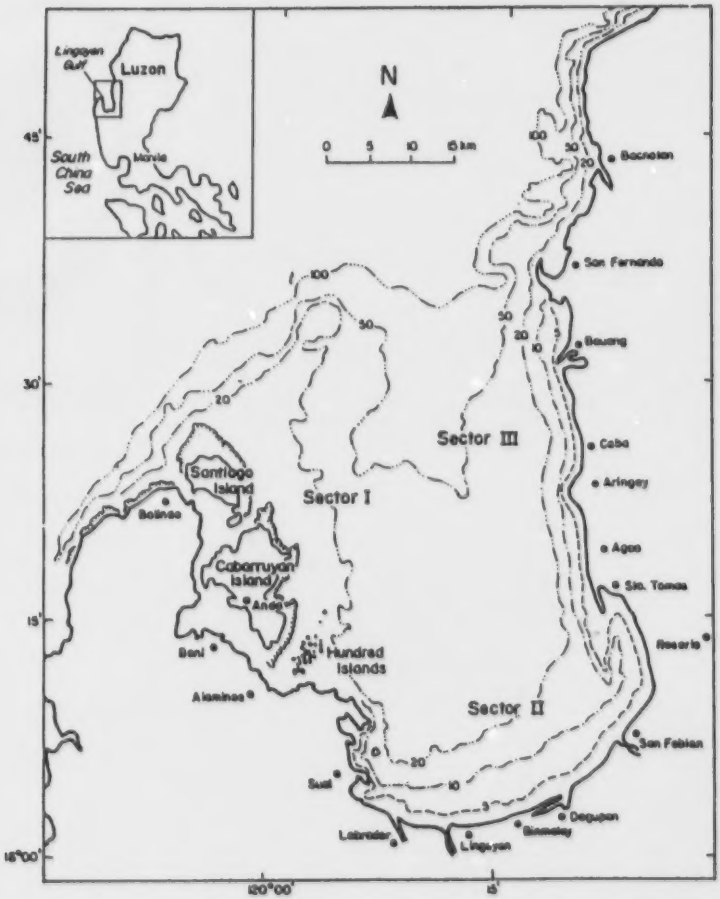

Fig. 1 The Lingayen Gulf, Northwestern Luzon, Philippines.

Table 1. Criteria for brackishwater aquaculture potential sites.

Parameter	Criteria
Soil Type	Excellent to good soil types for brackishwater ponds are clay, clay loam and silty clay loam. Fairly good are sandy loam (at least 35% sandy), loam or silt with clay size fraction (<0.005 mm) content of at least 20%. Hydrosol (good category) has high clay content but is acidic. Ponds built with this soil type require liming and repeated flushing to neutralize acidity.
Physiography	Tidal flats are regularly exposed to tidal fluctuations, are excellent for siting fishponds. Beaches are good to fairly good depending on the soil type (at least <10% sand is good category). Alluvial landform can be fairly good provided it is within 5 km distance from the shoreline or 3 km distance from tidal rivers.
Slope	Coastal areas with 0-8% slope are generally suitable with 0-3% slope being excellent. Construction of ponds that rely on gravity for drainage or tides for water exchange should have slope between 0-3%. In terms of elevation, this is between 0 to 1.8 m from tidal datum (mean low water, MLW). For farms that will use pumps, slope up to 8% is still suitable provided elevation should not be more than 5 m from tidal datum.
Erosion and flooding	Areas with no to slight for erosion and flooding are suitable. The former is given the highest rating.
Land Use	Marginal areas within 5 km from the shore and coconut plantations rank high priority for conversion to aquaculture farms than agricultural areas. However, economic analysis is required to assess opportunity cost of conversion (not done in this study). Degraded mangrove lands (alienated) are also priority for conversion except in areas gazetted for mangrove reforestation. Buffer zone of mangroves should be maintained along riverbanks and seashore, however.
Settlements	Settlements, especially major ones should be demarcated. Ponds should be sited away from major settlements to minimize pollution from domestic wastes. No attempt to demarcate (i.e., actual boundary) settlements has been made in this study due to the unavailability of cadastral or settlement maps.
Roads	Suitable sites should be within 3 km from village or private roads and within 10 km from municipal or provincial roads. Delivery of farm products and supplies will incur some cost per unit distance from the road so that easy access to roads entails lower cost.
Fishponds	Existing fishponds should be excluded in the final analysis to determine the exact potential sites.
Buffers	Buffer zones along river banks, shorelines and roads are necessary as setback lines for fishpond development. About 50-m buffer is considered on both banks of rivers while 100-m buffer for the shoreline. These should be planted with mangroves as protection from wave action.

Table 2. Site selection criteria for mangrove reforestation.

Parameter	Criteria	Ranking	Remarks
Physiography	Tidal flats	1	Regularly flush by tides
	Beach ridges and lines	2	Occasionally inundated at high tides
Soil Type	Clayey, clay loam	1	Suitable for most mangrove species
	Silty clay loam	1	like *Rhizophora* and *Avicennia*
	Sandy	2	Suitable for many non-mangrove species like coconut, *Casuarina*
Settlements	> 150 m distance	1	Buffer zone around settlements
	≤ 150 m distance	2	
Accessibility:			
from national roads	< 5 km distance	2	The further away the site from the road, the better to minimize disturbance from ongoing economic activities
	5 - 10 km distance	1	
from shoreline and rivers	0 - 3 km distance	1	Sites should be located along the seashore and riverbanks as protection against wave action in addition to its ecological functions for coastal waters
	3 - 5 km distance	2	

1: suitable; 2: less suitable

Other parameters not directly used in the overlay procedure:

Existing mangrove areas	This is to quantify the areal extent of existing mangrove areas including its location and present status. Useful in determining what level of reforestation/conservation effort is needed.
Old mangrove areas and nipa swamps	This is useful in determining the past areal extent of mangroves. Unfortunately, most of the mangrove stands in Lingayen Gulf were logged prior to the Second World War (converted to fishponds). Nipa swamps are closely associated with mangroves but of more direct economic importance. Hence, this is usually conserved by the local people.
Existing fishponds and other land uses	Existing fishponds and agricultural areas are not suitable areas for mangrove reforestation projects. Agriculturally non-productive areas and marginal lands (built-up areas) along the shore and river banks affected by tides are generally suitable for medium - large-scale reforestation projects (> 10 ha). For fishponds, mangrove planting along the periphery of dikes is desirable to protect against wave action. This is patchy and narrow, however, and does not contribute very much to the overall productivity of the coastal waters.

Table 3. Potential areas for brackishwater aquaculture.

Rank	Area (km²)	Area (km²)[a]
Excellent	8.95	0.49
Good	209.04	26.88
Fairly Good	134.47	134.47
Not Suitable	1,440.89	1,440.89
Existing Fishponds	148.25	146.02
Existing Mangroves	9.50	9.50

a Adjusted for mangrove rehabilitation.

Rank	Approximity to Water Sources: River 0 - 1 km Distance (km²)	River 1 - 2 km Distance (km²)	Shore 0 - 3 km Distance (km²)
Excellent	5.29	2.05	8.95
Good	110.48	24.76	119.22
Fairly Good	20.21	11.45	115.27
Not Suitable	267.76	192.86	339.33
Fishponds	112.87	10.58	98.79
Mangroves	4.84	2.70	1.40

Table 4.Potential Mangrove Rehabilitation Areas (Adjusted)

Rank	/.rea (km²)
Suitable	126.78
Less suitable	68.37
Fishpond areas	146.02
Existing mangrove areas	9.50
Ongoing mangrove projects	6.74

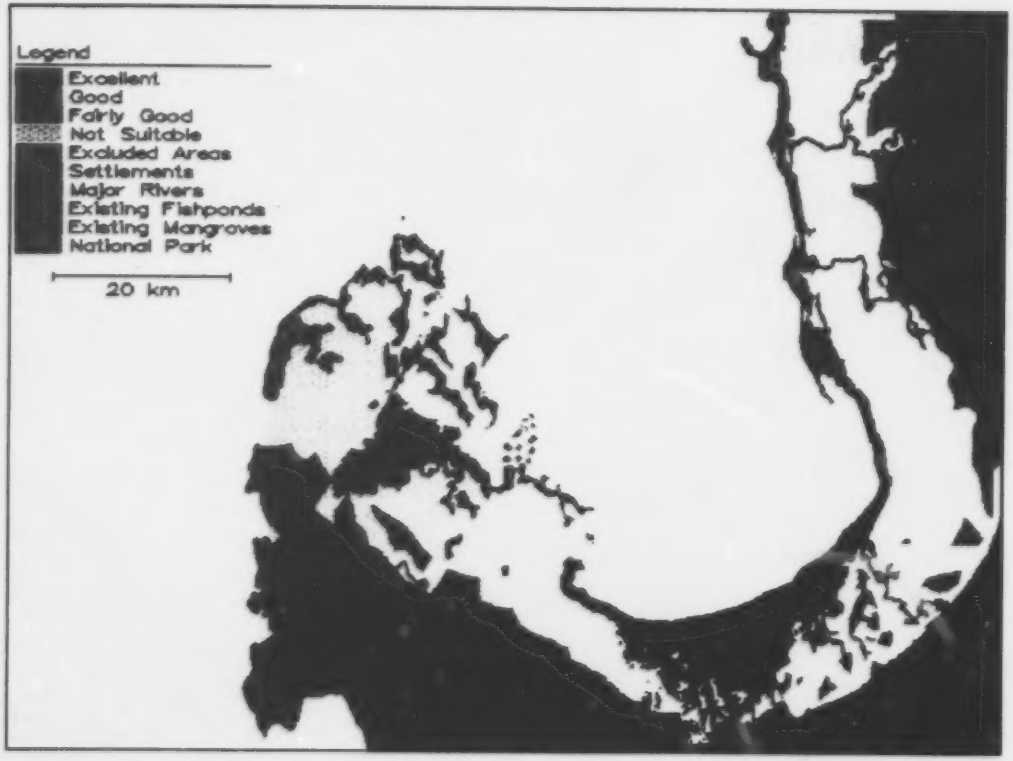

Fig. 2. Potential areas for brackishwater aquaculture.

Fig. 3. Potential areas for mangrove rehabilitation.

VIDEODISC MAPPING FOR COMMERCIAL VIDEODISC USE

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Abstract

Included is an outline and a brief history of commercial Videodisc use. The synopsis includes the early use for videodisc along with the present and future projects and implications of videodisc use. It also presents the advantages and disadvantages of commercial videodisc use, today and in the future.

CARTOGRAPHIE SUR VIDÉODISQUE
UTILISATION COMMERCIALE DU VIDÉODISQUE

RÉSUMÉ

Utilisation commerciale de la cartographie sur vidéodisque

L'entreprise Fifth Dimension est spécialisée depuis plus de 5 ans en intégration de systèmes dans le domaine de la technologie de l'image de pointe. Plus précisément, Fifth Dimension oeuvre depuis 1987 à fournir des applications cartographiques sur vidéodisque et à apporter de l'aide aux usagers du milieu militaire. L'entreprise s'est efforcée de promouvoir la mise en oeuvre de ces systèmes partout au Canada, dans les secteurs tant publics que privés. Des vidéodisques non-classifiés étant disponibles depuis peu, le nombre des installations commerciales pourra augmenter.

Le présent article passe en revue diverses possibilités et applications et examine le matériel et les périphériques nécessaires à un système fonctionnel

Fifth Dimension CAD/CAM Systems Inc. commenced operations in 1984, with the objective of supplying microcomputer based CAD and graphics systems to the Ottawa market. Since our inception, we have expanded our mandate to specialize in the design and provision of "turnkey" solutions in CAD, imaging and security access control as well as general personal computer standing offer business.

Fifth Dimension's Imaging Group has become a leader in the specialized field of designing and supplying imaging applications for use on micro-computer based systems. Traditional graphic arts processes can now be utilized on these more economical systems. We have developed extensive expertise in the areas of graphic video, digital computer technology, geographic information systems and document imaging.

5D has delivered a number of solutions which give us expertise needed to provide specialized imaging requirements. These include:

- the Canadian Airport Pass System which involved the capture, storage, printing and database associated with airport passes. This is a national system.

- development of the Fifth Dimension Restricted Area Pass Identification System which is a generic pass system including Windows interface and access control.

- numerous map image solutions based on Intelligent Television Corporation products for the Department of National Defence and Transport Canada. This system includes video disk images, gazetteer database, raster overlays and vector overlays.

- high resolution archives for National Archives. This system provides 4096 x 4096 high resolution colour images on computer screens.

Future Product Development Directions:

- To continue to support the specialized field of CAD & Imaging Systems Integration.
- To develop custom Image database applications from a defined tool set and providing turnkey solutions.

Fifth Dimension currently employees twenty-eight professionals and the company is privately Canadian owned and operated.

The term Optical disk refers to a disk on which information is recorded in the form of markings (pits, bumps, spots or marks) by an optical system. The optical recording system normally employs a laser. A common width of marking is 0.5 microns.

The term videodisc in this paper refers to a disk which:

a) is encoded in an analogue format for replay on a TV or TV-compatible monitor;

b) employs a similar recording density in bits per unit area to optical disk; and

c) is designed to be read using either an optical or electrical capacitance (non-optical) detection system.

Digital videodisc refers to analogue videodisc used to store digital data. Digital/analogue conversion is used with such disks. The term "analogue optical data disk" is used to refer to these disks. Videodiscs are categorized in numerous ways. Some of the principal categorizations are:

- digital/analogue
- optical/capacitance
- read-write; read-only; write-once; erasable
- direct read after write/pressed
- reflective/transmissive
- diameter size.

Analogue encoding is employed by consumer-market disks designed for playback of audiovisual materials, such as feature films, on TV or TV-compatible monitors.

a) Optical/capacitance

An optical disk is recorded using a light source, normally a laser. A similar light source, normally a lower-powered laser, is used for reading by current optical disk systems.

Capacitance systems employing magnetic encoding are not currently on the North American new-equipment market. Production of the only capacitance players sold in North America was discontinued in the spring of 1984; these were the Capacitance Electronic Disk (CED) players marketed principally by RCA.

Read-only systems can only read disks, write-once is a term used in contrast to erasable. Pressing is a process used to replicate disks from a suitable master. The process is similar to that used to replicate phonograph records; it is quick, cheap and used to mass-produce disks. Quantity-produced pressed disk have a much lower unit cost than direct read after write disks, which are generally lower in unit price for single disks or disks in very small quantities.

b) Reflective/transmission

Reflective disks have a mirror-like finish. If the disk is encoded on both sides, it must be turned over for reading the second side. Transmission disks do not need to be turned over to read the second side since the reading laser can be refocussed to read the second side through the disks,

which are made of translucent material. In spite of this advantage, the vast majority of optical disks are reflective disks.

c) Diameter size

The most common disk diameter sizes are 12 inches (30 cm.). This is a nominal size and not necessarily the exact measurements of the disk made by particular manufacturers.

The format for videodisc is not as standardized as that for CDADs (compact digital audio disc). Several very different formats are in use in North America. The largest number of disks sold to date are in the 12-inch diameter CED (Capacitance Electronic Disk) format used by the now discontinued non-optical CED system marketed principally by RCA. Since over half a million CED players were sold, and 12 million CED disks were sold in the year preceding RCA;s decision to cease production,there may be a continuing market for these disks even though players are no longer being manufactured.

RCA's decision to discontinue production of CED players appears to spell the demise of the CED system and leaves optical reflective videodisc as the major videodisc format. Major manufacturers of optical reflective videodisc players include Pioneer, Sony, Hitachi and Philips. Optical reflective videodisc players of one make can generally play disks made for another make of player, provided that play is straight-though and not interactive. Interactive play involves the reading of programs from the disk and their execution by the microprocess in/with the player. It is possible to master an interactive disk which will include programming to run on different makes of players. However, disks are normally mastered for one make of player. Interactive features can be used on the make of player for which the disk was mastered, but may not work

on other makes of players.

Twelve-inch diameter pressed, read-only, analogue, optical reflective videodisc are on both the North American consumer and institutional/industrial markets. Mass-produced consumer disks are used mostly for replay of feature film, general education and how-to material (for example, how to play tennis). Institutional/industrial market disks are commonly used for instructional purposes (for example, technician training); for promotional/publicity purposes (for example, US Army recruiting); entertainment (for example, arcade games); and for storage and retrieval of audiovisual materials (for example, art images) and mapping which is used for our applications.

Eight-inch diameter optical reflective videodiscs on the North American consumer market are used mostly for rock music and video. These disks can be played on the same players as 12-inch diameter optical reflective videodiscs.

Videodiscs can be produced in CAV (Constant Angular Velocity) or CLV (Constant Linear Velocity) format. In the CAV format, one video frame is recorded per track, or - more strictly - per 360 degree turn of the videodisc. This format provides random access to each frame and sharp freeze frame, but has a lower storage capacity than the CLV format.

With the CLV format, one video frame per track is recorded on the inner portions of the disk, expanding to three frames per track on the outer portions of the disk. Only limited random access is normally possible with CLV disks, and no freeze-frame, but CLV disks can hold twice as much data as CAV disks. Twelve-inch diameter CAV videodiscs store up to 54,000 NTSC (United States National Television System Committee standard) video frames per side with accompanying stereo sound. Twelve-inch diameter CLV videodiscs store up to 108,000 NTSC video frames per side with accompanying stereo sound. Playing time for 54,000 NTSC frames is 30 minutes, played straight through at 30 frames per second.

NTSC frames provide a resolution of approximately 50 x 50 lpi (lines per inch), not generally suitable for recording whole pages of text. An average of four NTSC frames per page was found to be required for the legible recording and playback of 8 1/2 x 11 inch pages of text.

The most nearly competitive system to videodisc is videocassette. Compared with videocassette systems, optical reflective videodisc systems have a number of advantages:

- much greater play-life;
- fast random access;
- for CAV format disks: random access to each frame on the disk and a sharp still frame which can be maintained over long periods without wear;
- superior picture quality to even high quality, high speed videocassette - reproduction of this quality on the monitor depends on the quality of the monitor;
- non-erasability - for applications where this is an advantage; and
- technical characteristics (for example, random access and still frame) much better suited for interactive computer-assisted applications such as interactive learning programs.

Compared to videocassette systems, optical reflective videodisc systems also have a number of

Disadvantages:

- disks cannot be erased and re-recorded;

Further Developments involving disk formats:

* Combination CD/Videodisc Players
* Computer peripherals
* Electronic Publishing
* Erasable disk systems

Advantages and Disadvantages of Videodisc Mapping

Advantages:

* compactness
* high storage capacity, particulary in relation to paper medium
* Multimedia: store and playback any form of image data, sound, and computer readable data.
* ability to store full colour and /or black and white images;
* ability to store high resolution images;

* ability to provide excellent image quality for separate replay or replay with moving images;

* resistance to general wear, tear, handling, dust, magnetic fields, and reasonable temperature ranges;

* play does not wear disks or reduce quality;

* resistance to vibration;

* precise random access;

* ability to provide low error rates;

* ability to remove disks and play multiple disks on a single player;

* suitability for computer controlled operation and as a computer peripheral;

* extended play freeze frame;

* high data transfer rate;

* non erasability of present disks;

* storage life generally quoted as more than 10 to 15 years;

* falling hardware costs and continuing improvements on the technology;

* rapidly expanding library of material;

Disadvantages:

* Expense to create disks and cost of peripheral items ie. videodisc players as compared to CD-ROM Players;

* Incompatibility of formats;

* Copyright infringement of material to be stored on disk;

- HISTORY OF VIDEODISC MAPPING IN CANADA

There is only one Videodisc that has been available to the Commercial and Industrial market in Canada and that disk was a prototype of Canada that was managed by Energy Mines and Resources in 1987. Now with new disks becoming reality as we speak, this now allows for the commercial and industrial agencies to use Videodisc mapping for its applications that only paper maps were used in the past. In so far as to explain a brief history of commercial Videodisc mapping in Canada, there seems that none is available.

Now with new disks being available it is like a rebirth of an old technology being that software has been readily available but that we have had not the medium with which to pursue the technology.

Canadian Government Agencies have been working with this technology since 1987 because of the availability of classified disks for their use.

Commercial and Industrial Agencies have already expressed interest in the past to Videodisc mapping, but were unable to fund such projects as they were expensive to undertake at that time.

VIDEODISC MAPPING AND FIFTH DIMENSION:

Fifth Dimension has been involved in Videodisc Mapping since 1988 mostly with government agencies. There has been a few commercial agencies that have expressed interest in the past but again the medium that they needed was not available to them.

Fifth Dimension has taken up the mandate to make all commercial and industrial agencies in Canada aware of what is now available to them involving **VIDEODISC MAPPING.**

VIDEODISC APPLICATIONS USED BY FIFTH DIMENSION:

Fifth Dimension is currently offering a product from Interactive Television Company (ITC) called FULCRUM for it's Videodisc applications.

Fifth Dimension is the only distributor of FULCRUM and related products in Canada and are here to offer support in the future for Commercial and Industrial agencies as well as Government.

FUTURE FIFTH DIMENSION APPLICATIONS WITH VIDEODISC MAPPING:

Future Videodisc applications within Fifth Dimension will firstly involve FULCRUM, with other applications ie... CD-ROM, DATABASE MANAGEMENT, and DOCUMENT AND GRAPHICS (MAPS) STORAGE AND RETRIEVAL being developed.

In the past Fifth Dimension has had to adhere to the Defence Mapping Agency's standards and will continue to do so in the future.

APPLICATIONS FOR COMMERCIAL USES

Hydro

- Legal Affairs
- Repairs
- Emergency Response
- Updating Databases

Railways

- Legal Affairs
- Repairs
- Emergency Response
- Updating Databases

Pipelines
- Legal Affairs
- Repairs
- Emergency Response
- Updating Databases

Municipalities
- Emergency Response
- Repairs
- Fire
- Police
- Ambulance

Large Corporations
- Emergency Response
- Repairs
- Fire
- Police

VIDEODISC-BASED MAPS

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Abstract

Dr. Steven Levin of Interactive Television Company, Arlington, Virginia, will provide a presentation on videodisc-based maps, including a demonstration of their use in FULCRUM, ITC's multi-source data display software.

This presentation will cover the history of the maps-on-videodisc product, a detailed description of production methods, and a discussion of strengths and weakness compared with other "electronic" map technologies such as ADRG, DCW, WVS, etc.

A full demonstration of FULCRUM will follow. This software system is used at hundreds of military and intelligence organizations around the world, and was applied to a broad range of activities in Desert Storm. Dr. Levin will highlight the use of a variety of map resources under FULCRUM, and discuss the future development path of this geographic data tool.

.Cartes sur vidéodisques

RÉSUMÉ

L'auteur traitera des cartes sur vidéodisques et fera une démonstration de leur utilisation avec le logiciel FULCRUM (ITC) à affichage de données multi-sources.

La présentation comportera un historique de la cartographie sur vidéodisque, une description détaillée des méthodes de production et une discussion des forces et des faiblesses de cette technologie par rapport à d'autres techniques de cartographie "électronique" telles ADRG, DCW, WVS, etc.

Une démonstration complète du FULCRUM suivra. Ce logiciel est utilisé par des centaines d'organismes militaires et de services de renseignement du monde et a été appliqué à une gamme étendue d'activités de l'opération DESERT STORM. L'auteur illustrera l'utilisation d'une diversité de ressources cartographiques avec FULCRUM et parlera de l'avenir de cet outil de données géographiques.

An Evaluation of the Use of Differential GPS in a Municipal Application

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ABSTRACT

With local and regional governments favouring the use of Geographic Information Systems (GIS) for data storage and analysis, the need arises for ongoing maintenance of the database. For the City of Scarborough, the goal was to find a quick and cost-effective method of maintaining topographic data. Currently, the database is maintained by personal inspections and ground surveys of the features in question using conventional surveying techniques. This task tends to be tedious and expensive to the taxpayer. This paper describes the use of the Global Positioning System (GPS) in differential mode, as a tool to complement the existing method. The study was conducted in the City of Scarborough, Ontario, with the features collected consisting of known survey control markers. The field data was compared to existing, ground-surveyed coordinates. Results indicate that differential GPS is a satisfactory method to maintain topographic databases due to its ease of use, effectiveness and accuracy.

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Évaluation de l'utilisation du SPG différentiel dans un contexte municipal

RÉSUMÉ

Comme les administrations publiques locales et régionales favorisent l'utilisation de systèmes d'information géographique (SIG) pour le stockage et l'analyse des données, il faut constamment mettre à jour la base de données. À la ville de Scarborough, le but était de trouver une méthode rapide et économique pour mettre à jour les données topographiques. La base de données est actuellement mise à jour lors d'inspections personnelles et de levés de terrain des entités en question au moyen de techniques de levés classiques. Cette tâche a tendance à être laborieuse et coûteuse pour le contribuable. Le présent article décrit comment le système de positionnement global (SPG) est utilisé dans différents modes comme outil complémentaire de la méthode existante. L'étude a été menée à Scarborough (Ontario), les entités relevées étant des repères géodésiques. Les données de terrain ont été comparées aux coordonnées de levé de terrain. Les résultats indiquent que le SPG différentiel est une méthode satisfaisante pour mettre à jour des bases de données topographiques à cause de sa facilité d'utilisation, de son efficacité et de sa précision.

INTRODUCTION

Topographic Data

Topography can be defined as a collection of the earth's surface features, both natural and man-made. These features consist of visible elements such as buildings, roadways, signs, waterways or non-visible elements such as underground utilities. The City of Scarborough, like most municipalities, uses topographic data to fulfill its daily business functions [Sussman and Bannon, 1991]. These functions include the provision of services to internal departments (Building, Planning and Fire), external departments (Ministry of Revenue and Ontario Hydro) and private agencies (Bell Canada and Scarborough Cable TV).

The Metropolitan Toronto Public Utility Co-ordinating Committee (MTPUCC) categorizes topographic mapping into two levels of precision: 0.30 m accuracy suitable for display at a scale of 1:500, and 3.0 m accuracy suitable for display at 1:10,000. Currently, Scarborough uses information provided by ground surveys and personal inspection to maintain the 0.30m database. This method has proven to be tedious, inconsistent and costly to the taxpayer.

Global Positioning System

The Global Positioning System (GPS) is a satellite-based positioning and navigation system developed by the United States Department of Defence (DoD), and available to both military and civilian users. In November 1991, sixteen of the twenty-one GPS satellites were in orbit and transmitting normal signals. Full operational capability is expected by the end of 1992. A user on the surface of the earth will be able to receive signals from at least five satellites at any one time.

There are two different ways of using GPS signals. One involves measuring range to four or more satellites using one of the code modulations, known as C/A (Coarse/Acquisition) and P (Precise). This code phase measurement is the standard technique used in most navigation receivers. Using the C/A-Code, this method provides instantaneous position fixes with an accuracy on the order of 30 metres, 2-drms (2-dimensional root mean square) when Selective Availability is not active.

The other technique provides relative positioning of two or more receivers by measuring carrier phase information as well as pseudoranges (code phase). This method is commonly used with GPS surveying equipment and can provide results which are accurate to better than a few centimetres over short baselines. However, the receivers must remain stationary for a considerable period in order to achieve full accuracy.

Selective Availability (SA) is a mechanism applied to the

transmissions from the satellites in order to reduce the positioning accuracy obtainable, for reasons of United States national security policy. When SA is enabled, the achievable accuracy with a single receiver using the C/A-Code is approximately 100 metres 2-drms. However, the effects of SA may be largely overcome by the use of differential GPS (DGPS).

DGPS is a variant of conventional GPS code phase measurement processing in which a stationary GPS receiver at a precisely surveyed location is used to determine instantaneous errors in the position solution. These errors may then be used to correct the position fixes obtained by one or more mobile units within a range of up to 500 kilometres from the base station. This may be done either in real time using a communications channel, or by means of off-line processing.

From the above it can be seen that DGPS provides the great benefit over carrier phase processing of providing quick results for those users who can tolerate the lower accuracy. Although a slight improvement in accuracy is possible by averaging measurements over a number of seconds, instantaneous fixes may be adequate for many users. In some applications, vehicle-mounted receivers are used to capture positions for features such as roads. In these cases the data may be collected with the vehicle continuously moving, rather than making stops to record data at fixed locations.

The concept of using GPS for mapping topographic features and assigning attributes is still a relatively uncharted frontier. However, many projects have used GPS to obtain precise positional data. Experiments in the Baltic Sea tested the use of differential GPS for ships navigating through the hundreds of islands in the Swedish archipelago [Tryggö and Bäckström, 1991]. Other projects include ground truthing using GPS in Guatemala [Miller, 1991], and the use of GPS for forest fire management and cleanup [Drake and Luepke, 1991].

A related project local to the City of Scarborough was the one conducted by the Town of Markham, located at the northeastern fringe of Metropolitan Toronto, Canada, in 1989 [Treitz et al., 1991]. Their intent was to discern whether GPS could be used in topographic map revisions. Their findings concluded that GPS proved to be efficient and accurate in the maintenance of a topographic database.

PROJECT PURPOSE

The goal of this study was to evaluate the potential use of GPS in the municipal environment for the maintenance of existing digital topographic mapping. The specific objective was to test the level of accuracy achievable and the efficiency of data collection using differential GPS equipment.

STUDY METHOD

Resources

The study was carried out by Bill Howes and Mitch Raymond from the City of Scarborough, with support from Jon Jones of Acrostar. Additional support came from the GIS and Administration Division of the Works and Environment Department of the City of Scarborough. The GPS equipment used was the Acrostar Geologger II equipment. This is a small battery-powered system which consists of an antenna, a receiver unit and a hand-held computer which is used to control the system, and to log the time, position, attributes and other data. Identical systems were used for the base station and mobile units, except that the base station computer contained 4 MBytes of RAM memory rather than the 1 MByte of the mobile unit. A personal computer was used for post-processing of data in the office.

Study Location

The City of Scarborough encompasses 18,700 ha in area with a population of approximately 510,000. About half of the city is residential, a fifth industrial and roughly 12% public parkland, school site, institutional, utility corridor or open space. Scarborough is the only municipality within Metropolitan Toronto still undergoing the development of new sub-divisions from rural lands.

Map 1 illustrates the study area. For consistency purposes, the topographic features collected consisted only of third-order control markers. Locational data sheets were selected for sixteen control markers (see Table 3). The control markers were surveyed to a ratio of 1:40,000. The markers were grouped into four areas: two residential, one industrial, and one shoreline.

Data Collection and Processing

Data was collected using the two Geologger II GPS data loggers in differential mode. One unit was used as the base station and was located at Ellesmere Yard, at the intersection of Ellesmere Road and Midland Avenue, which is close to the geographic centre of Scarborough. The antenna was placed on the roof of the building, in order to provide good visibility of the sky down to the horizon. Coordinate values for the antenna location had previously been determined to an accuracy of 0.30 metres by graphical means using a digital drawing. The coordinates are given in Table 4.

The second Geologger II data logger was used as the mobile unit. Data collection was conducted on the morning of 11th October, 1991. The features consisted of third-order control markers located throughout the City of Scarborough. The work was carried

out using a two person crew. One person operated the Geologger II and entered the attributes for the feature, and the other positioned the antenna, which was mounted on a range pole, over the control marker. Three readings were taken for each feature. The first was taken after 5 seconds, the second after 30 seconds and the third after 5 minutes with the antenna remaining stationary on the feature during this time.

With the use of the Acromark post-processing software, the base station and mobile data files were transferred from the data loggers and differentially processed. The corrected NAD-83 (North American Datum 1983) geographic coordinates were then converted to 3° MTM (Modified Transverse Mercator) cartesian coordinates in units of metres. The accuracy of these coordinates was then determined by comparing the northing and easting to the survey coordinates for each control marker. The errors for the measurement taken at each time interval were then accumulated and averaged.

RESULTS

Table 1 illustrates the field data that was actually collected. The values were rounded to the nearest centimetre.

Table 2 displays the difference between the field results (Table 1) and the control marker specifications (Appendix A). The differences are measured in metres for the northings and eastings. For each time interval, the differences are averaged as indicated at the bottom of the table.

Table 2 shows that, on average, the accuracy of the results obtained increased when the mobile antenna remained over the feature for thirty seconds, compared with the results at five seconds. For the thirty seconds duration, average errors of 2.349 and 1.713 metres were recorded for the northing and easting respectively.

The reason for the relative inaccuracy of the five second readings is not known, however, it is thought that filtering processes within the receiver which have long time constants may not have reached steady state at the five second point.

The average error after a stay of five minutes is seen to be greater by 20% and 42% compared to the thirty second data, for the northing and easting respectively. The reason for this increased error is not known, however, it may be the result of changes in the constellation of satellites selected by the receiver occurring during some of the data collection sequences over the longer interval. When the receiver drops one satellite and selects another, it is known from other work that instantaneous errors may be introduced into the position solution.

DISCUSSION

During this study, no attempt was made to collect and average several position data over a period of time. It is considered likely that some improvement in accuracy could be obtained by using this procedure due to the averaging of random error processes which would occur. In addition, it is thought that using averaged data taken over a period of 30 seconds or 1 minute would help to provide assurance concerning the accuracy of individual position points recorded.

GPS in differential mode is capable of collecting data more quickly and with smaller crews in comparison to the existing method of collecting data with a total station. For total stations, valuable time is lost in station setup whereas little, if any, is needed for GPS. This lack of setup time results in more net time for data collection and less total time in the field.

Another positive feature of the GPS equipment used for this trial is the reduced crew size needed for operation. If a tripod were used to support the antenna, crew size could be reduced to a single individual. This would provide additional cost savings for organizations whose budget constraints limit the extent of data collection. When used for the collection of linear features such as roads, data collection can be done by attaching the antenna on the vehicle's roof. This method would greatly improve the speed with which road data collection could be carried out.

The Geologger II GPS software has the ability to assign attributes to features while in the field. The speed at which this is accomplished is comparable to feature entry with total stations.

Existing methods of topographic data collection, notably total station field surveys, high-resolution photogrammetry, and static and kinematic GPS, commonly have accuracies of 0.30 m or better. It is therefore necessary to compare the higher productivity and lower cost of differential GPS equipment with the greater accuracy of these other methods prior to making an administrative decision as to whether differential GPS should be used.

The accuracy obtained using differential GPS is unacceptable for legal surveying practices, where accuracy of 0.3 metres is required; however, it is acceptable in maintaining many features or attributes in topographic mapping.

The ability to obtain an accurate position using any GPS equipment depends on the number of satellite signals which can be received and on the geometric arrangement of those satellites with respect to the receiver. These parameters are affected by the current orbital configuration and by the environment in which the receiver is to be operated. The path of GPS signals is in the line of sight from each satellite to the antenna. The

requirements of satellite geometry dictate that it is necessary to receive signals from some satellites which are at low elevation angles (e.g. 10° above the horizon) in order to achieve maximum accuracy. Many municipal environments contain obstructions to GPS signals, such as buildings, bridges and trees; these may prevent the optimum geometry from being attained.

However, since the number of satellites visible and their arrangement in the sky are continuously changing, the problem can often be overcome by carefully selecting the time of day at which the measurements are performed. Using mission planning software such as that provided with the Geologger II equipment can eliminate the need to revisit problematic sites to repeat a set of measurements.

For the test data presented in this paper, no problems were experienced in the ability to acquire a sufficient number of satellites, even though the satellite constellation was not yet complete. However, there will certainly be occasions when it will not be possible to obtain a high accuracy GPS position for a particular feature due to obscuration of signals.

CONCLUSIONS

To effectively maintain a topographic database, information must be efficiently and accurately gathered. Differential GPS was found to be a effective method of achieving this for the City of Scarborough. It has been shown in this study that differential GPS can satisfactory locate features, and, by inference, maintain a topographic database to accuracies of 3.0 metres. Accuracy levels achieved in this study met the MTPUCC standards for Medium Scale Mapping.

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Table 1 - Field Data Results

Ctrl Marker Number	5 Seconds N	5 Seconds E	30 Seconds N	30 Seconds E	5 min. N	5 min. E
020700338	4848079.52	329871.45	--	--	4848072.07	329870.19
021660025	4848096.19	329874.13	4848096.19	329874.13	4848096.30	329874.13
020792149	4848146.24	329857.84	4848146.24	329857.84	4848146.13	329857.84
020782361	4848264.53	329822.53	4848260.85	329817.15	4848262.75	329821.17
020792150	4848323.79	329803.47	4848323.78	329802.11	4848321.89	329800.83
020782119	4846710.29	325834.50	4846710.29	325834.50	4846706.50	325830.49
020782124	4846618.56	325526.07	4846618.56	325527.44	4846618.56	325527.44
020782118	4846756.25	325751.10	4846756.25	325751.10	4846754.35	325749.74
020782117	4846661.79	325742.06	4846661.79	325742.06	4846661.79	325742.06
020822121	4845481.89	320922.96	4845485.66	320921.58	4845483.78	320922.95
020822122	4845567.27	321038.24	4845567.27	321039.60	4845565.49	321039.61
020681123	4845608.13	321074.38	4845610.02	321074.37	4845621.15	321082.40
020822211	4845569.45	321113.37	4845569.45	321114.78	4845561.91	321118.78
020822120	4845276.53	320990.62	4845276.53	320990.62	4845276.52	320989.25
020660625	4836948.25	322510.69	4836944.47	322509.33	4836948.26	322514.72
020660626	4837118.42	322459.12	4837118.42	322457.75	4837116.53	322457.83

Table 2
Differences between Field Results and Survey Coordinates (metres)

Ctrl Marker Number	5 sec. N	5 sec. E	30 sec. N	30 sec. E	5 min. N	5 min. E
020700338	5.757	7.605	--	--	1.693	8.865
021660025	1.141	0.915	1.141	0.915	1.251	0.915
020792149	0.185	0.971	0.185	0.971	0.075	0.185
020782361	0.810	2.644	2.870	2.736	0.970	1.284
020792150	0.549	2.478	0.559	1.118	2.449	0.162
020782119	0.067	0.031	0.067	0.031	3.857	3.979
020782124	0.579	1.579	0.579	2.349	0.579	2.349
020782118	4.599	0.349	4.599	0.349	2.699	1.011
020782117	1.114	0.538	1.114	0.538	1.114	0.538
020822121	5.139	9.326	8.909	10.706	7.029	9.336
020822122	4.489	1.453	4.489	0.093	6.269	0.083
020681123	4.192	0.564	2.302	0.574	8.828	7.456
020822211	3.768	1.233	3.768	0.177	3.772	4.177
020822120	1.001	1.107	1.001	1.107	1.011	0.263
020660625	3.600	0.101	0.180	1.461	3.610	3.929
020660626	3.475	1.200	3.475	2.570	1.585	2.490
Average	2.529	2.006	2.349	1.713	2.924	2.939

Table 3 - Control Marker Specifications

For convenience, third-order horizontal control markers were used. Listed below are their station numbers and their respective environment, with the 3° MTM coordinates for each marker.

Area	Marker Number	Northing (m)	Easting (m)
Residential Area			
(Warden Av./Lawrence Av. E)	020822121	4845476.751	320932.286
	020822211	4845565.682	321114.603
	020822120	4845277.531	320989.513
	020822122	4845571.759	321039.693
	020681123	4845612.322	321074.944
(Morningside Av. /Kingston Rd.)	020792150	4848324.339	329800.992
	020782361	4848263.720	329819.886
	020792149	4848146.055	329856.869
	020700338	4848073.763	329879.055
	021660025	4848095.049	329873.215
Shoreline Area			
(Queen St./Victoria Park Av.)	020660625	4836944.650	322510.791
	020660626	4837114.945	322460.320
Industrial Area			
(Bellamy Rd./Lawrence Av. E.)	020782124	4846619.139	325525.091
	020782119	4846710.357	325834.469
	020782118	4846751.651	325750.751
	020782117	4846660.676	325741.522

Table 4 - Base Station Antenna Location

3 Degree MTM Coordinates

Easting	323129.458 m
Northing	4847498.400 m
Elevation	170.000 m

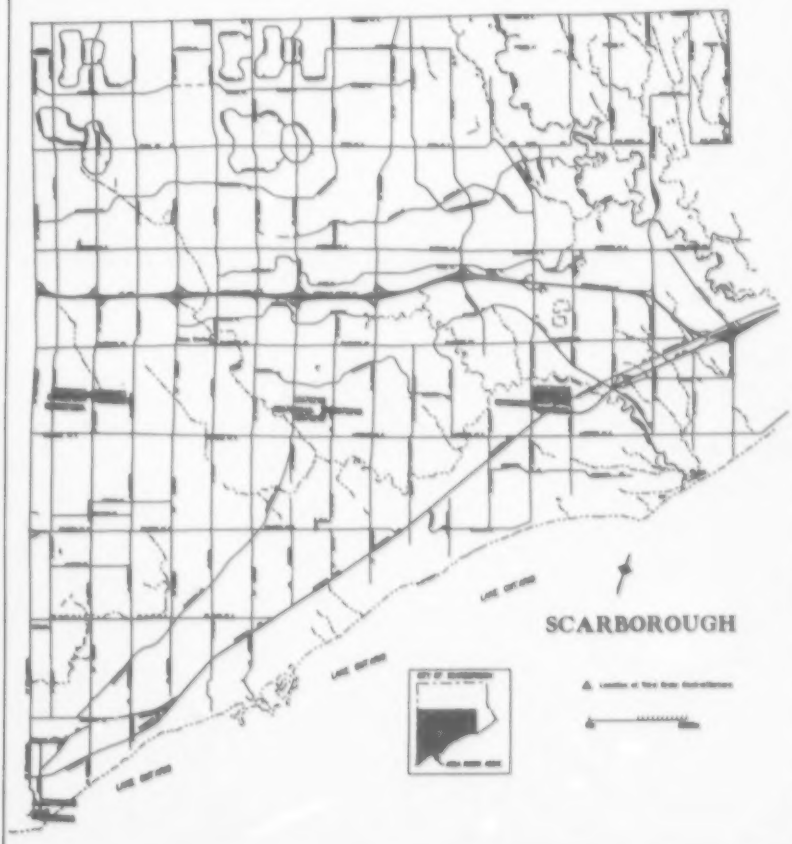
Geographic Coordinates (relative to NAD-27 Datum)

Latitude	N 43° 46' 08.985"
Longitude	W 79° 16' 20.407"
Elevation	170.000 m

Supplemental Information

Projection: 3 Degree MTM (Modified Tranverse Mercator)
Central Meridian: W 79° 30' (corresponding to x-coordinate value of 304800 m)
MTM Zone: 10
Clarke 1866 Spheroid

Map 1. Location of Control Markers



REGISTRATION AND INTEGRATION STRATEGIES FOR REMOTE SENSING IMAGERY IN SPATIAL INFORMATION SYSTEMS

STRATEGIES POUR L'ENREGISTREMENT ET L'INTEGRATION DES IMAGES DE TELEDETECTION DANS LES SYSTEMES D'INFORMATIONS A REFERENCE SPATIALE

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ABSTRACT

Remote sensing imagery can provide most important information for setting up and updating spatial information systems (SISs). However the nature of the errors affecting most remote sensing imagery and the uncertainties in the information often complicate the registration and integration procedures. Following an overview of the principal error sources with examples of their implications, different strategies for the registration and integration of remote sensing imagery in SISs are described and compared. The discussion includes suggestions to deal with uncertainties in the data as well as quality control procedures to analyze the results. General conclusions and recommendations then follow in view of attempting to automate as much as possible the registration and integration procedures for remote sensing imagery in SISs.

RESUME

Les images obtenues par télédétection peuvent fournir des informations des plus importantes pour l'élaboration et la mise à jour des systèmes d'informations à référence spatiale (SIRS). Cependant la nature des erreurs affectant la plupart des images de télédétection et les incertitudes dans les informations compliquent souvent les procédures d'enregistrement et d'intégration. A la suite d'une revue des principales sources d'erreurs avec exemples des implications, différentes stratégies pour l'enregistrement et l'intégration des images de télédétection dans les SIRS sont décrites et comparées. Les discussions incluent des suggestions pour traiter les incertitudes dans les données de même que des procédures pour le contrôle de la qualité pour l'analyse des résultats. Des conclusions générales suivront en vue d'automatiser dans la mesure du possible les procédures d'enregistrement et d'intégration des images de télédétection dans les SIRS.

1.- INTRODUCTION

Remote sensing imagery has long been recognized as a natural and cost effective source of data for setting up and updating a Spatial Information System (SIS). Essentially, remotely sensed data can provide a variety of spectral information with a range of spatial and temporal resolutions. Advances in digital image processing methodology offer new possibilities to handle image distortion, raster and vector format conversions and integration, uncertainties in the information and proper feature extraction and processing.

Although the rectification, registration and integration of remote sensing imagery in SISs have been carried out for some time, several outstanding problem areas remain and deserve further investigations for the development of adaptive procedures. Specifically, when dealing with different data sources, possibly including multi-sensor, multi-spectral and multi-temporal data, numerous problems clearly require further research and development work to arrive at automatic adaptive procedures for implementation in production environments.

In general, Remote Sensing (RS) image data represent the result of a one-dimensional sampling in the time domain and a two-dimensional sampling in the spatial domain. Basic properties of a remote sensor can be expressed in terms of:

- spectral coverage and resolution,
- spectral dimensionality (i.e. number of bands),
- radiometric resolution (quantization),
- instantaneous and angular field of view (IFOV),
- point spread function,
- temporal response function

[Davis and Simonett, 1991; Strahler et al., 1986]. These characteristics can vary greatly between sensors and types of terrain coverages. Adaptive methods for RS image processing need to take these variable factors into consideration.

From the perspective of acquisition and recording processes, RS data types are normally two-dimensional raster data sets of imagery, or profiles in vertical and/or horizontal directions, or image cubes of continuously sampled parts of the electromagnetic spectrum. Interpreted, classified or segmented RS data tend to be the results of irreversible transformations of the raw data into several general classes of intermediate data which are planned for information extraction purposes. Generally then, these data sets are raster image data of specified classifications, or vector data sets of profiles, contours, and so on.

The integration process involves proper restoration, rectification and shape matching of features before implementing the actual registration procedures. A key step in the process is the necessary distortion analysis in order to handle the registration problems. Shape matching of features can be signal based or object based but with the current transition to object oriented procedures, object based shape matching offers better possibilities.

In traditional applications, Geographical Information System (GIS) data types span a wider range of sources than those used in traditional RS applications. Generally, GIS data types can be classified as raster data, vector data, or other data types such as field data, deterministic model data and survey measurements. It is perhaps worth noting that in SISs, the geographical information generally constitutes only a subset of the spatial information which can be considered for inclusion. With the evolutionary trends in GIS design objectives and applications, the designation SIS is becoming more and more appropriate.

For GIS and RS data to be integrated into a SIS, data models and structures have to be properly analyzed for:

- spatial entity types (points, lines, regions, etc.),
- object handling (encapsulation, inheritance, etc.),
- space partitioning (regular grid, data determined, etc.),
- data structuring (cell based, object-relationship based, etc.),
- time considerations (permanent entities, temporary effects, etc.).

[e.g., Frank and Barrera, 1990]. Depending on the applications, the data models and structures have to satisfy requirements from simple feature handling to knowledge representations and processing. Full integration implies that all the interconnectivities and other characteristics of the combined information have been taken into consideration and merged in the combined databases.

The integration process involves feature extraction and modeling for proper inclusion of the results into a spatial information system. Feature shapes and characteristics are therefore required for careful analysis before any matching can be attempted. However, it has to be expected that the information will often be incomplete and therefore uncertainty considerations will be necessary to handle many situations. Inference procedures have to be capable of dealing with incomplete information as the integration procedures and the subsequent users' queries cannot generally be restricted to completely specified situations. Clearly more research and development are needed on these questions.

2.- ERROR SOURCES IN REMOTE SENSING IMAGERY

During RS data acquisition and processing, several types of radiometric and geometric errors are introduced in the digital imagery as a result of abnormalities in the mirror scanning velocity, detector sampling delays, panoramic distortions, variations in spacecraft velocity, altitude and attitude, and so on. Bernstein et al. [1983] have given detail discussions of those errors and their nature, their significance and the techniques used in the correction procedures. Such errors can only be modeled to limited degrees of accuracy and reliability, and consequently, remote sensing imagery tends to be affected by the residual errors.

Environmental errors also affect RS imagery as a consequence of ground surface variations, atmospheric refraction, weather conditions and other less understood factors. Ground receiving stations normally process the RS data to remove most of the systematic errors, and calibrate the data to a common data base for the users of the information. Normally, the data processing is carried out to the requester's specifications but nevertheless, residual errors remain and users should be aware of the data limitations. Clearly, when data from various resolutions, different spectral bands and multiple epochs are involved, the spatial and spectral constituents of the RS imagery are more likely to suffer from the residual error implications.

Although several calibration and correction techniques have been developed in RS, it is not uncommon to have to use "rubber-sheeting" rectification procedures to remove residual distortion effects. Such correction techniques should always be considered only as a last resort when no explicit information is available about the nature of the residual errors. The situation is analogous to the complications encountered in converting positional information from NAD27 to NAD83 with no field observations available for any rigorous network integration [e.g., Blais, 1990].

Furthermore, it is also worth noting that the radiometric properties of the rectified imagery may differ significantly from the original situation as a result of resampling and other transformations [e.g., Duggin and Robinove, 1990]. Hence appropriate measures may have to be considered for any subsequent application of the corrected imagery. The geomorphology of the terrain clearly has important implications in this respect, implying that adaptive measures are necessary for most applications.

The registration process with RS imagery has traditionally been carried out using control points in operator assisted environments. The procedures are very similar to the well known photogrammetric point transfer techniques where the operator takes the neighborhood features and related information into consideration. The automation of the registration process tends to use control features rather than control points because of the identification problems with control points in RS imagery of limited resolution. It therefore follows that feature identification and extraction are likely to be required in the registration process. Shape matching is very often used in these operations and the object-based strategies are particularly effective in this context [e.g., Greenfeld, 1987; Lam, 1990] and will be further discussed in the sequel.

3.- DISTORTION ANALYSIS CONSIDERATIONS

The analysis of position and shape discordances between the RS imagery and GIS contents requires the matching of control point and feature images. Most often, control point images are difficult to match because of the resolution of the RS imagery and the different representations of the information in RS and GIS databases. For instance, a raster image of a control target may be impossible to match with a vector image of the same object which may not even be explicitly identified in the GIS database.

It is therefore imperative to consider shape matching of control features in order to derive the positional, directional and scale differences in various strategic locations of the RS imagery. The general procedure usually involves edge detection and focusing before the polygonal shapes can be defined and matched in terms of their vertices and associated attributes (more details can be found, e.g., in Lam [1990]; Blais and Lam [1991]). The resulting information leads to a distortion analysis of a difference vector field where the behavior in the neighborhood of critical points can be investigated for the optimal modeling of the discrepancies. The methodology for critical point analysis is well known in vector field calculus and system dynamics [e.g., Kaplan, 1973; Morrison, 1991].

Such investigations of the distortions may lead to refinements in the reduction process for the RS imagery. In other words, systematic effects may appear in sufficient magnitudes and extent that the RS imagery be considered for additional corrections. Furthermore, the GIS data may also be questioned in terms of positional accuracy and feature shape integrity. In any case, the discrepancies can be eliminated at the control locations and predictions can be formulated for corrections elsewhere. The situation is analogous to dealing with positional differences in other contexts where the modeling and corrections can be formulated in terms of first and second moment statistical information, as discussed in Blais [1990].

4.- INTEGRATION ERROR SOURCES

Residual errors constitute a major concern in any RS application and in particular, in any integration of RS imagery into a SIS. From a RS perspective, understanding the possible

sources and characteristics of potential errors involved in the integration of ancillary or other data sets by means of a GIS in an analysis has been considered an important research topic for some time. Conversely, remote sensing can and does provide a significant source of input to GIS analysis. As such, GIS and SIS users are also very concerned about the types and magnitudes of the residual errors wherever RS data are utilized [Star et al., 1991].

The integration of RS and GIS information into a SIS occurs more naturally with a raster GIS because both data structures are approximately the same, but differences in the attribute and other characteristic information can complicate matters in practice. Basic image processing and analysis tools such as geometric corrections and pattern recognition are expected to be available to preprocess RS information into a form in which attributes are assigned to raster data instead of raw data values from spectral bands of multi-spectral imagery.

Integration of RS and GIS information in the case of a vector GIS requires somewhat more effort but it has been recently achieved by several GIS and RS vendors, at least to the extent of updating vector information by using an image as a backdrop for vector editing [Fraust et al., 1991]. With a topologically structured object based GIS such as SYSTEM 9, which includes comprehensive capabilities of dealing with spatially-related information, the integration of RS imagery into the GIS is still relatively complicated when the data structuring, updating and processing aspects are considered [Zhou et al., 1991].

5.- REGISTRATION AND INTEGRATION TECHNIQUES

From the previous discussion, following the analysis of RS image spatial, temporal and spectral characteristics, their related source and processing errors, and GIS data features, basically three strategies which are point based, object based and knowledge based integration can be implemented in practice. These are discussed in the sequel:

(a) Point Based Registration and Integration

With this approach, the corresponding points in the GIS database and RS imagery are identified through human interpretation, or as a byproduct of automatic edge detection. The registration model parameters are then calculated with error statistics using those selected points. The model and parameters can then be refined through control editing according to the available error information. When a certain accuracy threshold is achieved, the RS imagery is geo-coded into the GIS database as backdrop or for further processing, possibly with some data linked with it.

This technique is simple to use and can be made adaptive with the help of the displayed error graphics. The error in model and control points can be identified and easily corrected. One shortcoming is that it requires human intervention and therefore is difficult to automate. Furthermore, for near featureless imagery or in cases of repetitive features, it would be difficult to select good and reliable control points, as well known from similar photogrammetric control transfer situations.

(b) Object Based Registration and Integration

Object oriented operations use objects or features as basic elements in the integration. Therefore, the RS imagery first has to be polygonized so that the objects or features can be identified. The corresponding objects need to be located in the database through their geometric attributes such as angles, lengths and areas, using also topological aspects such as

left, right, inside and outside. Other attributes such as object names, associations and correspondences can also be used in some instances. The matching and registration are then performed through global transformations of the object shapes into the RS imagery.

Object based methods are most appropriate for object oriented GIS databases where they can easily be automated. The information used is more comprehensive than in point based approaches and its robustness is likely to be better under scale changes, orientation differences and possibly variable noise levels. Difficulties are likely to arise in the segmentation and classification prior to the feature identification. Tolerance to different noise levels can also be a problem in some applications.

(c) Knowledge Based Registration and Integration

Ambiguities can easily arise in object based applications that cannot be resolved with simple algorithmic procedures. Computational requirements and calibration difficulties may also imply the need for alternatives or improvements to object based techniques. Knowledge based approaches include rules and decision procedures to take care of such problematic situations. The acquisition and representation of knowledge in terms of facts, rules and conventions are complex problems for most knowledge based approaches. Their development is usually best done in prototype environments before attempting any production implementations.

Knowledge based image registration and integration represent the state of the art in current research. Future GISs and SISs will undoubtedly become knowledge based expert systems which will include wide ranging information from various sources, including RS imagery.

6.- QUALITY CONTROL AND UNCERTAINTY CONSIDERATIONS

Integration of RS imagery and GIS contents leads to the conceptualization of the process as a flow of spatial data through a series of transformations from the real world into a SIS. Such an information process can be analyzed in terms of information representation and conservation. Quantification of the information loss throughout this process is clearly a research area of high priority for better quality control and handling of the uncertainty in the contents of the information system.

One practical approach to information management is to keep a record of the data sources and the data processing operations carried out. In some applications, an additional attribute can be included to record the accuracy of intermediate results in the different processing stages in order to facilitate the quality control of the resulting information. Such an integrated solution to monitoring the process flow of information has been described by Lanter [1990, 1989]. The approach involved the development of a Lisp program which tracked the manipulation of data products in an ARC/INFO environment. Ongoing research is focusing on the application of this methodology to the modeling of error accumulation in GIS products [Lanter and Veregin, 1990]. Another similar investigation was carried out by Miller [1991] and some further research and development are currently being done towards generalizing the procedures.

Uncertainty as incomplete information requires proper modeling and quantification for the inference procedures. In practice, processing operations have to be carried out whether the information is complete or not, and the results have to reflect the limitations in the inference results. Information theory has provided much insight into the processing of incomplete information in inverse and related problems [Blais, 1991a and b]. The possible applications of

information theory to the problems of uncertainty management in information systems are under study.

Uncertainty is not to be identified with lack of accuracy or lack of well defined boundaries as any incompleteness of the information contributes to the uncertainty. Actually, some of the very important sources of uncertainty have nothing to do with accuracy or boundary definitions. For instance in object reconstruction, parallax or phase information is a strict requirement for spatial definition and no additional accuracy in the data can substitute for it. In photogrammetric terms, height information cannot be extracted from single imagery immaterial of the image quality and accuracy.

How to deal effectively with incomplete information in the context of spatial information processing is not a simple matter in general. In most applications, a good strategy consists in making use of any prior information available with proper considerations for the available data. Furthermore, the inferences using such an information based approach are subject to revisions whenever new observations or any other information become available. More details on the information theory applications and information based inference can be found, for instance, in Blais [1991a and b].

7.- DISCUSSION AND CONCLUDING REMARKS

RS imagery offers important sources of information for setting up and maintaining a GIS and more generally, a SIS. The errors affecting the RS imagery need to be properly modeled so that appropriate corrections can be applied for the registration and integration of the imagery into the SIS. It is also worth noting that the GIS or SIS should not be considered errorless in general as all types of errors may have gone undetected until the RS imagery is considered for integration.

Distortion analysis of the discrepancies between the RS imagery and the GIS contents can provide most valuable information for the decisions required to resolve the problems. With sufficient information, it is relatively straightforward to estimate the error characteristics and design correction procedures. However, incomplete information is to be expected in general, and more sophisticated strategies are required to avoid making inappropriate inferences and thereby biasing the results. The recording of the decision steps for the data processing operations can be most useful in the proper management of uncertainties in the RS imagery integrated into a SIS.

Adaptive methods and procedures are definitely required for the automation of the registration and integration operations as conditions can greatly change with location and time. Quality control procedures are also needed to ensure that the integrity and other characteristics of a SIS are not compromised as a result of the integration of the RS imagery.

Uncertainty in the database contents can be a major obstacle in various data and information processing applications. In other words, the incompleteness in the information can make decisions very difficult to justify because of some unknown implications. Quantifying and characterizing the information in some probabilistic manner appear to imply the most appropriate methodology for such problems.

Further theoretical and practical investigations are clearly warranted to fully exploit the potentials of RS imagery in GISs and SISs. With the advances in computer technology which

include object oriented applications environments and specialized software, the future SISs can only be expected to have fully integrated RS and other imagery as a standard feature.

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SYSTEME D'INFORMATION A REFERENCE SPATIALE BASE SUR DES DONNEES DE TELEDETECTION POUR LA CONSERVATION DES EAUX ET DES SOLS (CAS DU BASSIN VERSANT DE L'OUED MERGUELLIL EN TUNISIE)

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Résumé

L'objectif de cette étude est de développer le potentiel des SIRS et de la télédétection pour l'étude des problèmes liés à la dégradation des ressources naturelles en Tunisie et d'établir une méthodologie d'utilisation de ces données et techniques en vue de préserver ces ressources. Le bassin versant de l'Oued Merguellil, qui couvre environ 154 000 ha dans le centre du pays, a été choisi comme site du projet. Le projet comportera en gros trois étapes : la première consiste en l'analyse de la démarche de travail et des besoins en information de la Direction de la conservation des eaux et des sols (DCES) et de ses partenaires dans le domaine de la lutte contre l'érosion; la deuxième étape verra le développement d'un prototype rapide de système d'aide à la décision; et la troisième étape verra le développement d'un système adapté aux besoins de la DCES et aux qualifications de son personnel, selon la méthode du prototype évolutif à partir de l'évaluation du prototype rapide. Le projet est échelonné sur trente six mois. Une meilleure connaissance des contraintes, possibilités et limites de l'intégration de l'information spatiale aux processus et méthodes de prises de décision et la mise au point d'une méthode de classification d'images basée sur l'utilisation de variables non spectrales comptent aussi parmi les résultats scientifiques attendus du projet.

GEOGRAPHICAL INFORMATION SYSTEM BASED ON REMOTE SENSING DATA FOR WATER AND SOIL CONSERVATION OF THE OUED MERGUELLIL WATERSHED IN TUNISIA

Abstract

The goal of this project is to develop a geographic information system for the conservation of natural resources in Tunisia. Remote sensing data will provide a significant amount of information for the proposed GIS. The study area (154 000 ha) is the Oued Merguellil watershed which is situated in the center of Tunisia. Three main phases of the project have been identified. The first phase will concentrate on the analysis of the information requirements of the user agency (DCES). A prototype GIS will be developed during the second phase. The final phase of the project will be the development of a GIS specifically adapted to the user agency's information needs. The project will focus on the problems and constraints of the integration of spatial data into management and decisional processes.

1. Introduction

Si l'érosion n'est pas un phénomène nouveau en Tunisie, elle revêt d'année en année une intensité plus inquiétante. En soixante dix ans, l'espace rural tunisien a subi des bouleversements considérables. Les terrains mis en culture en 1920 étaient estimés à 1,2 millions d'hectares, actuellement ils dépassent 5 millions d'hectares. La même année, la population tunisienne était évaluée à 2 millions de personnes, depuis elle a plus que triplé. Cet accroissement démographique a mené à un défrichement considérable de la végétation naturelle, considérée comme étant la meilleure protection anti-érosive et a également entraîné la mise en culture de terrains auparavant utilisés comme parcours, étendant les labours à des sols marginaux accidentés, très sensibles à l'érosion. Le contrôle du phénomène d'érosion est basée sur une nouvelle conception qui a tendance à faire des programmes de conservation des eaux et des sols des projets d'aménagement intégré des bassins versants, qui, en plus de leur objectif initial de protection, accordent une grande importance à l'amélioration des rendements et à la production agricole en général.

En effet, d'après des études réalisées différents facteurs rendent les sols tunisiens particulièrement vulnérables à l'érosion. Ces facteurs sont :

1- climatiques: l'agressivité et l'irrégularité des précipitations provoquant des crues brutales et épisodiques.

2- édaphiques: la Tunisie possède peu de sols évolués et riches en humus en raison de l'action de l'érosion qui contribue à créer continuellement des sols jeunes alluviaux ou colluviaux ou directement issus de la roche mère qui est à prédominance marneuse ou argileuse.

3- topographiques: le relief de la Tunisie bien que peu élevé, présente en général des terrains à pentes raides qui accélèrent considérablement le phénomène de l'érosion.

4- socio-économiques: la couverture végétale de la Tunisie a été profondément transformée par l'homme, dont le mode de vie connaît lui aussi des transformations considérables. En effet, le défrichement de la végétation naturelle, la mise en culture de terrains de parcours et la pratique de procédés culturaux inadéquats ont favorisé l'intensification des phénomènes d'érosion et des transports solides vers l'aval.

Pour atténuer les conséquences de l'érosion, améliorer le bilan hydrique des terres et favoriser le couvert végétal, l'effort déployé inclus la réalisation de retenues collinaires qui jouent un rôle primordial dans la vie des populations rurales concernées; ainsi que la réalisation d'aménagements de conservation des eaux et des sols.

L'objectif de cette étude est de développer le potentiel des SIRS et de la télédétection pour l'étude des problèmes liés à la dégradation des ressources naturelles en Tunisie et d'établir une méthodologie d'utilisation de ces données et techniques en vue de préserver ces ressources. Le bassin versant de l'Oued Merguellil, qui couvre environ 154 000 ha dans le centre du pays, a été choisi comme site du projet.

2. Problématique

La définition, la concrétisation et le suivi d'une

politique de conservation des eaux et des sols nécessite une bonne connaissance des conditions naturelles du milieu (géomorphologie, géologie, écologie, pédologie, etc.) et sociales (niveau de vie, activités socio-professionnelles, etc.) qui seule permettra d'identifier et d'élaborer des projets d'aménagements intégrés techniquement réalisables, socialement acceptables et économiquement rentables.

La démarche d'élaboration des projets d'aménagement suit le processus classique, avec les phases suivantes:

(a) phase de planification: étude préliminaire des caractéristiques du milieu permettant de dégager les zones prioritaires, soit celles qui sont les plus menacées par l'érosion.

(b) phase de programmation: étude plus détaillée des zones prioritaires afin d'identifier les aménagements appropriés.

(c) phase d'exécution: élaboration des plans d'exécution et réalisation des diverses actions anti-érosives.

(d) phase de contrôle et de suivi: surveillance de l'impact des travaux effectués sur le milieu et sur le rendement agricole (évaluation agro-socio-économique).

Vu les activités évoquées ci-dessus, le volume et la diversité des informations nécessaires pour les exercer, la difficulté de les récolter et de les tenir à jour, ainsi que la complexité des processus d'analyse et de prise de décision, il est nécessaire de moderniser les outils de captage et de gestion des données, et d'intégrer ces outils modernes aux activités des ingénieurs et décideurs de la DCES. C'est ainsi que la sélection des zones critiques, la conception générale des ouvrages de protection anti-érosive (études de variantes, choix et étude générale des solutions retenues), et l'étude du comportement hydrographique du bassin versant, seront effectués de manière efficace, et précise par l'emploi des outils et techniques numériques actuelles de l'ingénieur; mais celles-ci impliquent de recourir aux données captées, gérées et tenues à jour dans un SIRS développé dans ce but.

Jusqu'ici, l'utilisation par la DCES des techniques de télédétection, en tant que mode d'acquisition de données, et celles des SIRS, pour la gestion et l'analyse des données et l'exécution des diverses études (phases (a), (b) et (d)), a été très faible. L'exploitation de ce potentiel permettra d'améliorer la connaissance des divers phénomènes concernés, et améliorera fortement la qualité des études et aménagements, tout en permettant des gains de temps appréciables.

Le développement d'un SIRS efficace et adapté aux buts ci-dessus nécessite l'intégration en une méthodologie cohérente des techniques de captage et de tenue à jour des données, de leur structuration et de leur application aux diverses activités décrites plus haut. Divers travaux (Leclerc et al., 1989; Leclerc et al., 1986; Golay, 1991) ont montré que les approches actuelles des SIRS doivent être adaptées aux besoins spécifiques des applications en génie; en particulier, la structuration des données, leur mode de captage et les processus de transformations formelles et informationnelles à appliquer aux données d'un SIRS pour les besoins du génie doivent faire l'objet d'études plus approfondies.

La segmentation d'images est une technique relativement nouvelle d'analyse d'images qui exploite la dimension spatiale en plus de la dimension spectrale de l'image. La segmentation permet

de diviser l'image en entités spatiales spectralement homogènes. Cette technique a déjà été testée pour des applications en télédétection (Stakenborg, 1986; Bénié et al., 1987; Corr et al., 1989) et, lorsque combinée à une méthode de classification de segments, a démontré une amélioration significative de la précision des classifications principalement avec des images de haute résolution comme SPOT. Or, toutes les études tendent à démontrer qu'il reste énormément de recherche à faire surtout lorsque l'on veut intégrer des informations contextuelles au processus de classification des segments pour améliorer sa précision.

3. Objectifs

L'objectif général du projet est de développer une méthodologie de développement et d'utilisation conjointe des techniques des SIRS et de la Télédétection pour les études de génie rural relatives à la protection des ressources en eaux et des sols en Tunisie. Au-delà du développement d'un outil (le SIRS), il vise à développer la connaissance profonde des mécanismes de captage et de transformation des données nécessaires aux études techniques, ainsi que la formation de chercheurs, cadres professionnels et des enseignants tunisiens qui auront la charge de développer et d'exploiter cet outil, et de former le personnel qui devra travailler à son développement et à son application.

Les objectifs spécifiques du projet sont:

(a) l'identification des besoins et des contraintes sur un tel SIRS

(b) l'analyse de son environnement humain, institutionnel et informationnel

(c) la description du cahier des charges du système de gestion de données localisées (SGDL) adapté à un tel développement

(d) l'inventaire et l'analyse des mécanismes et des techniques de captage, de transformation et d'analyse des données relevantes

(e) l'analyse détaillée des activités mentionnées ci-dessus, de leurs besoins spécifiques en informations, et des méthodes et logiciels utilisés ou utilisables

(f) l'application des nouvelles techniques d'analyse des images satellitaires pour en extraire les informations nécessaires relatives à la couverture et l'utilisation du sol

(g) en particulier, le développement et l'application des méthodes d'exploitation conjointe de la segmentation et de l'analyse discriminante des images, d'une part, et d'autres données disponibles (cartes, etc.), et leur intégration subséquente dans le SIRS (Fig. 1).

(h) la mise en place des infrastructures humaines, techniques et organisationnelles nécessaires au fonctionnement et à l'exploitation à long terme d'un tel système

4. Résultats

A la fin de ce projet, échelonné sur 36 mois, outre les résultats en terme de ressources humaines et ceux organisationnels et politiques, les résultats scientifiques attendus sont les suivants:

- développement d'une méthodologie relative à la mise en oeuvre intégrée de ces techniques géomatiques (SIRS et

télédétection) dans le domaine de la lutte contre l'érosion

- meilleure connaissance des contraintes, possibilités et limites de l'intégration de l'information spatialisée aux processus et méthodes de prises de décision, dans la perspective du développement de véritables systèmes d'aide à la décision (Decision Support Systems - DSS)

- mise au point une méthode de classification d'images d'avant-garde complète et basée sur des techniques de pointe, soit: la segmentation et l'utilisation de variables non spectrales pour la classification des segments

- amélioration du potentiel d'utilisation conjointe des techniques SIRS et télédétection pour l'identification de sites potentiels d'érosion dans le bassin du Merguellil, l'élaboration des bases de prise de décision (analyse, cartes, etc.) et la préparation des bases pour les études de détail et le suivi des projets.

- amélioration des possibilités de mise en valeur et de la protection des terres agricoles, de protection et de la prolongation de la durée de vie des infrastructures, et d'impact des travaux de protection contre l'érosion sur l'évolution des nappes souterraines.

5. Methodologie

5.1 Localisation géographique

Avec celui de l'oued Zeroud, le bassin versant du Merguellil, choisi comme site du projet, assure la collecte des eaux de la Tunisie centrale depuis la frontière tuniso-algérienne à l'ouest jusqu'à l'amont immédiat de la plaine et la ville de Kairouan. Il se situe entre les longitudes $7^{G}55$ E et $8^{G}35$ E et les latitudes $39^{G}60$ N et $39^{G}78$ N. Il couvre environ 154000 Ha (Fig. 2).

L'oued Merguellil est connu depuis longtemps par la rareté de ses ressources en eaux pérennes et par la violence redoutée de ses crues. L'apport solide du Merguellil est estimé à 5,5 millions de m^3/an. Son régime hydrologique particulier a retenu l'attention de tous les responsables d'aménagements et d'équipements depuis fort longtemps. En effet, l'eau dans cette région constitue un élément très précieux et très redouté. Il reçoit une pluviométrie annuelle de 200 à 400 mm avec 40 à 70 jours de pluies, contrôlée par 8 stations pluviométriques et pluviographiques.

Le bassin présente une surface en grande partie montagneuse et relativement homogène. Le cours principal draine la majeure partie du bassin versant et s'écoule d'ouest en est. L'indice de compacité et le dénivelé spécifique indiquent un bassin allongé à reliefs forts. Il est caractérisé par une importante érosion.

5.2 Méthode

La première étape du projet débutera avec l'inventaire détaillé et l'analyse du potentiel de la documentation de base susceptible d'être utilisée, en particulier des données de télédétection (Landsat/Spot) et des données cartographiques, photographiques ou autres disponibles dans les divers organismes concernés.

La méthodologie à développer et les systèmes d'information et d'analyse d'images doivent servir l'activité de la DCES; le projet se poursuivra donc par une analyse de la démarche de travail et des besoins en information de cet organisme et de ses partenaires dans le domaine de la lutte contre l'érosion, qui servira de base aux deux étapes suivantes.

La deuxième étape du projet verra le développement d'un prototype rapide du système à réaliser, avec les buts suivants:

- description des besoins en information, selon les résultats de la première étape;
- développement des structures de données nécessaires;
- choix et tests des méthodes et techniques de captage;
- prototypage des opérations d'analyse et de traitements d'images;
- définition des fonctionnalités nécessaires pour les divers aspects du fonctionnement du système (captage, gestion, transformation et communication, analyse et interprétation, prise de décision, suivi des projets, etc.);
- présentation de l'avancement de la recherche aux futurs utilisateurs;
- élaboration du cahier des charges du système à acquérir pour la suite du projet et la réalisation de production.

Utilisé comme moyen de communication entre les divers partenaires et intéressés au projet, l'utilisation de la méthode de prototypage rapide prendra toute sa valeur. Le fait de pouvoir non seulement décrire par des phrases ou des schémas, mais simuler de manière aussi réaliste que possible les fonctionnalités de l'outil développé, on renforce l'efficacité et on facilite la bonne communication entre tous les partenaires du projet. Il permet de plus un avancement plus rapide et cohérent de la recherche, en facilitant l'intégration des développements partiels effectués à des sites différents. Dans ce type de prototypage, le système développé est en général abandonné une fois les fruits de l'expérience récoltés.

La troisième étape se déroulera selon la méthode du prototypage évolutif, effectué sur le système acquis à partir de l'évaluation du prototype rapide. La complexité du problème et le degré encore élevé d'incertitude rend, en effet, nécessaire sa solution par étape, selon les priorités et le calendrier fixés dans la deuxième étape.

Tout au long du projet, on procédera à l'analyse et à la traduction des développements en termes de méthodologie de travail applicable à d'autres cas que celui de l'oued Merguellil; on s'attachera en particulier à l'identification des types de traitements appliqués aux diverses étapes du travail, et des structures de données les plus adaptées (raster, vecteur, données non spatialisées, etc.) pour les divers besoins.

6. Conclusion

Cette étude en cours de réalisation cherche à développer une méthodologie d'utilisation conjointe des techniques des SIRS et de la télédétection. Le développement s'effectue en étapes selon la technique des prototypages rapide et évolutif. La segmentation d'images permettra d'améliorer les résultats de classification obtenus sur les données spectrales et d'assurer une mise à jour efficace du SIRS.

7. Remerciements

Ces travaux seront réalisés grâce à une subvention du Centre de recherches pour le développement international, Ottawa, Canada.

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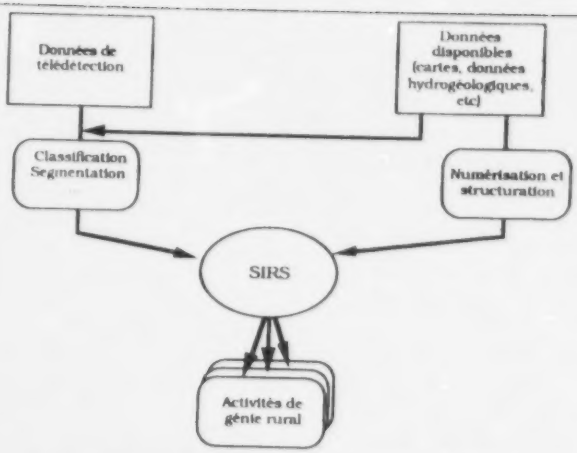

Figure 1 - Exploitation des technologies SIRS et télédétection pour le génie rural

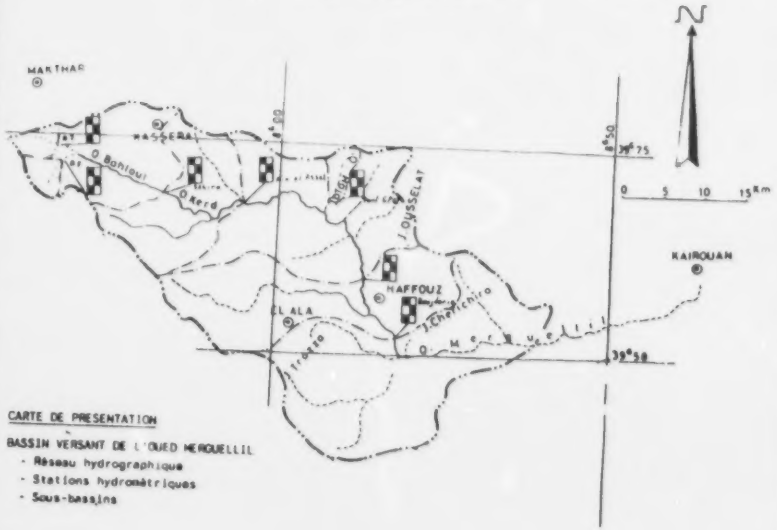

Figure 2 - Localisation géographique du bassin versant du Merguellil

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Title of paper: **'First Step to the Information Era in the Dongting Lake Region – Dongting Lake Geographic ..formation System'**

Abstract: The research on the design of the database of the dyke surrounded area (Shorten as DSA) in the Dongting Lake Region had started from 1985. It is one of the national projects in the last 'Five Year Plan' period and funded by IDRC. Through three year efforts, the expected tasks of the project have been successfully accomplished. Applied software for flood forecasting and flood damage evaluation was developed by ourselves with more than 10,000 programming commands. The created database included 34 dyke surrounded areas (DSA's) within the range of 19 cities and counties in the Dongting Lake Region, Jingjiang reach of the Yantze River and Jingjiang flood division area. Numerous research reports about environmental changes, index atlases, papers, and monographs have been published. All the results and equipment have been transferred to the Human Remote Sensing Centre.

1) The DSA database contains socio-economic statistic data, terrain maps, hydrological data, flood control facilities information, ???? ??? ?????? ???? ??? landsat TM data, etc. Some of the techniques were successfully applied to flood management in the middle reache of the Huaihe River. The experiences indicate that we will be more skillful in flood forecasting, flood damage evaluation, disaster relief, and the reconstruction after the disaster with GIS.

2) The system has to the Jingjiang reach ???? ???? ???? ???? ???? ???? proving the flood control capability and benefits of the Gezhou Dam and planning Three Gorges Dam in the Yantze River.

3) The Dongting Lake Region and the Jianghan Plain are rice and fish land which produce most commodity grains in China. With the function of these databases and CIE, more contribution will be made in the next 'Five Year Plan' period on wet land use, agricultural and urban development patterns. These subjects have been identified as key projects in the following five years.

4) In the conceptual design of the GIS for the Dongting Lake Region, the physiographical phenomenons and the environmental change features of the Lake Region and Jianghan Plain, the simulation and calculation of the lake evolution trend have been analyzed and evaluated in full detail. The result has won high praise from the International Space Year.

5) Thoughout this project, we have paid special attention to its typical land form - dyke surrounding area. Thorough analysis has been given to this basic geographical unit for simulating the dynamic process of flood diverting gate, and formulating wetland use and planning. The research results are of great value in flood control decision making, facilities maintenance, and management, and crop pattern.

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<<Première étape vers l'ère de l'information dans la région du lac Dongting - le système d'information géographique du lac Dongting>>

RÉSUMÉ

On a commencé en 1985 la recherche sur la conception de la base de données concernant la zone endiguée (ZE) de la région du lac Dongting. C'est un des projets nationaux du dernier plan quinquennal; il est financé par l'IRDC. Au bout de trois ans d'efforts, les tâches prévues étaient réalisées avec succès. Le logiciel utilisé pour prévoir les inondations et évaluer les dégâts qu'elles causent a été élaboré par nous, et comporte plus de 10 000 commandes de programmation. La base de données créée couvre 34 zones endiguées (ZE) réparties sur 19 villes et comtés de la région du lac Dongting, sur la partie Jingjiang du Yantze et sur la région des inondations du Jingjiang. On a publié de nombreux rapports de recherche sur les changements environnementaux, atlas, documents et monographies. Tous les résultats et le matériel ont été transférés au centre de télédétection du Hunan.

1) La base de données de la ZE contient des données statistiques socio-économiques, des cartes topographiques, des données hydrologiques, des renseignements sur les installations de gestion des crues, (illisible), des données de cartographie thématique Landsat, etc. Certaines des techniques ont été appliquées avec succès à la gestion des crues dans le cours moyen du Huaihe. L'expérience montre qu'avec le SIG, nous pourrons mieux prévoir les inondations, en évaluer les dommages, intervenir pendant le désastre et procéder à la reconstruction après.

2) Le système concerne le Jingjiang (illisible), prouvant la capacité de limiter les inondations et les avantages du barrage du Gezhou, et permettant la planification du barrage des Trois Gorges sur le Yantze.

3) La région du lac Dongting et la plaine de Jianghan sont propices à la riziculture et à la pêche, et produisent la plus grande partie des produits céréaliers de Chine. Avec l'aide de ces bases de données et du CIE, on pourra contribuer plus au prochain plan quinquennal en ce qui concerne l'utilisation des terres humides, et les modèles d'aménagement agricole et urbain. Ces sujets ont été désignés comme projets clés pour les cinq prochaines années.

4) Pour la conception du SIG sur la région du lac Dongting, on a analysé et évalué en détail les caractéristiques des phénomènes physiographiques et des changements environnementaux concernant la région du lac et la plaine du Jianghan, ainsi que la simulation et le calcul des tendances évolutives du lac. Le résultat nous a valu des éloges lors de l'Année internationale de l'espace.

5) Tout au long du projet, nous avons porté une attention particulière à sa forme caractéristique, celle d'une zone endiguée. Une analyse soigneuse a porté sur l'unité géographique de base pour la simulation du processus dynamique des ouvrages de diversion des inondations et pour la formulation de l'utilisation et de la planification des terres humides. Les résultats de la recherche sont très utiles pour la prise de décisions sur la maîtrise des crues, pour l'entretien et la gestion des installations, de même que pour les caractéristiques des récoltes.

FIRST STEP TO THE INFORMATION ERA FOR DONGTING LAKE REGION
——Dongting Lake Geographic Information System

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1. Background

Dongting lake region in Hunan province in middle Yangtze River covers 19 counties(cities) and 15 state farmlands with 18,780km square, and has a population of 6,500,000, a cultivated area of 8,000,000 mu, which is about 1 / 6 of the whole Hunan province, and a rice field of 5,730,000 mu. "Better harvests in Dongting, Better life for country". The region is one of the most important bases for the grain and fish production of commodities, and play a decisive role in socio-economic development of Hunan province.

The region is a alluvial plain with an average sea level of 25-50m, which is charcterized by smooth terrain, concentrated water net and farming land with fertilized soil. To use these richly endowed land, the region is protected by dykes which are taken as a main measure for flood control and surround the region into 34 area, called dyke-surrounded area (DSA, Fig. 1). Dykes built count up to 5800km. and the total area of DSA is about 12,600km square. But the rate of building dykes can not catch up with the rising speed of flood level resulted by sediment depositing in lake bed. The top elevation of main dykes is 1 to 2 meters higher than the flood peak level in 1954, 1% flood.

It is Yangtze River that brings up lakes of Dongting, Poyang and Hunhu in its middle reach(Fig. 2). They play a important role in regulating flood during peak period. But in last fifty years, the linkage between the river and lakes in north side had been broken. The floods have to discharge into Dongting lake through four branch outlets, and take along about 100 millions cubic meters sediment each year. From 1951 to 1987, there were 4 billions cubic meters sediment deposited in lake and river bed, averagely raising the bed about 1m and increasing 60,000mu lake beaches each year. The lake capacity was reduced 40% from 1954 to 1983, the area was reduced to 2740 km square in 1985 from 4350 km square in 1954. If the 1954 flood re-occured, the flood peak level would be 3-5 m higher than before, which would cause huge damages. For example,, the flood flow diverting from Yangtze River in 1983 was about 50% of in 1954, but the flood level was 2m higher than 1954.

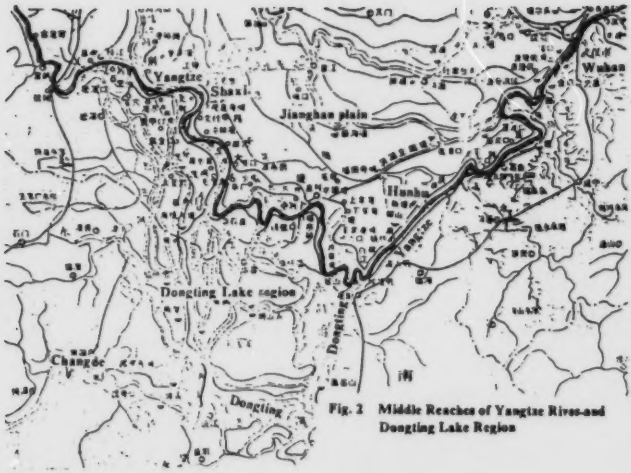


Fig. 2 Middle Reaches of Yangtze River and Dongting Lake Region

2. Flood Control Schemes

Before the three-Gorges Dam of Yangtze River built, the main flood control scheme in Dongting lake region is of building dykes to limit the rivers and lakes, and to protect the developed land where provide 25% grain, 90% cotton and 50% silk of Hunan province. In recent years, local settlers put 1 / 3 labours to heighten and reinforce the dykes for 3 to 6 months. the costs of flood control and drainage are amount to 30 yuan / person. Since it is so, when scarce flood event occured, some of dykes would be broken to divert the flood for lowing the level in lake and Yangtze River for protecting the more important region of Jianghan plain and Wuhan municipality from flood damage.

Flood damage evaluation and flood diversion area management is two of problems faced by local and state government for reducing the damages caused by flood and flood diversion.

Effective flood-diversion management requires the estimation of the damage associated with a specific flood event. Once the decision of diversion made, almost whole flood diversion area face the risk of inundation. The differency of damages in different sites depends on the distribution of flood depth , last time, safety facility, goods etc. So it is necessary to do the spatial analysis of flood.

Flood diversion area management has some unique features that make it different

from approaches adopted elsewhere. It focuses on both of protection and diversion. The area will bear most of the burden of disaster relief and recover costs for their settlers. They have to build the safety facility, do evacuating program, recover planning and goods prepareness.

In addition to mitigate flood diversion losses, the spatial analysis of flood plain and flood control facility with GIS will contribute to it.

3. Dongting Lake Geographic Information System

The system objectives is of collecting, organizing and packaging environmental and socio-economic spatially-related data to improve the efficiency of decision-making in dealing with flood control and management in Dongting lake region of China. The implementation of creating this system was divided into two steps: first is of creating spatial database of DSA and second is of developing analysis model, establishing user interface. After 5 years' effort, these two step works have been successfully implemented.

The research on Dongting lake geographic information system started in 1985. It is one of the state projects in the last "Five-year Plan" period, and funded by the International Development Research Center of Canada. Through the united effort made by State Key Laboratory of Resources and Environmental Information System of CAS, Hunan Remote Sensing Center, Chinese Academy of Agriculture Sciences, Nanjing University, Peking University. Zhejang University and Ministry of Water Resources etc. The expected tasks of the project have been successfully accomplished. About 34 professors, experts, engineers and technicians from the above units and institutes have made their joint efforts. The compaq / 20e micro computers, digitizer, plotter were purchased, which are fitted with PC-ARC / INFO GIS software,which funded by IDRC, Canada, and applied software for flood forecasting and flood damage evaluation that developed by ourselves with more than 10,000 programing commands. The database created includes 34 dyke surrourded areas(DSA) within the range of 19 cities and counties in the Dongting Lake Region, Jingjang reach of Yangtze River and Jingjang flood division area. Numerous research reports, index atlases, papers and monographs have been published. All the results and equipment have been transferred to Hunan Remote Sensing Center, the local operation and maintenance agency.

(1) The research on DSA database and Dongting Lake—GIS is under the leadership and support of the Ministry of Water Resources, SSTCC and National Remote Sensing Center. The design of Dongting lake GIS is based on the criteria of on-going system to meet user's multi-level information requirement, which consistes of database, updating

technologies and analysis models. The DSA database stored all kinds of data(Fig. 3): socio-economic statisitic data, terrain maps(Fig. 4), hydrological data, flood control facilities information, aerial side-looking radar images and landsat TM data and so on. The DSA database is a paticular spatial data structure in GIS. It is neither a simple vector, nor a simple raster, but a mixture structure. It reflects island uints on a broaden water surface area of the river network. The successful experience of this creating experiment has practical adaptability in the research and estabishmeat of database in the delta areas of large rivers, multi-lake regions and multi-island coastal areas. The updating technologies are a series of methods for registration of remotely sensed data, extraction of remote sensing information and collecting of other non-remotely-sensed data. The analysis models is for the tendency forecasting of Dongting lake, environmental change study, flood simulation, damage evaluation and information support of decision-making on flood control and management. Some of the software were successfully applied to information support in 1991 flood disaster decision-making in the middle reach of the Huaihe River. The disaster losses have been evaluating in less than half hour after requirement of central flood control headquarter, which provide a strong tool of flood control and water-logging prevention. By equiped with the database and GIS, we will be more skillful in flood forecasting, flood damage evaluation, disaster relief and recover planning. The project has achieved beneficial experiences for the design and establishment of data base and GIS for those area where flood and waterlogging frequently occur in China and abroad.

(2) During the conceptual design of Dongting GIS, the physiographical phenomenous and environmental change features of the region and Jianghan Plain were taken as the basis of creating system. By simulation and calculation of lake evolution trend, the main causes of Dongting lake evolution are the results of global climatic change and sea level fluctuation historically. The direct causes are the disapperaence of Yenmen lake, former lake in north Yangtze River, reclaimation of the beaches along two sides of Yangtze River, and blocking of the distributaries of Yangtze in north side. The serious floods occured are continually depositing sediment in river and lake bed which finally will make Dongting lake dead and form a new lake. The result has won high appraise from the International Space Year. And the region has been identified as one of the typical areas for the global environmental change.

(3) Throughout this project, Special attention has been paid to its typical land form—dyke surrounded area. Each of the DSA is a relatively separate flood control unit. Therefore, complete analysis has been given to it. The two dimensional flood wave model has been used to simulate the dynamic procession of flood diverting, flood water depth and velocity(Fig. 5), the location selected for flood diverting gate, wetland use and planning. The research results are of great value in flood control decision making, facilities

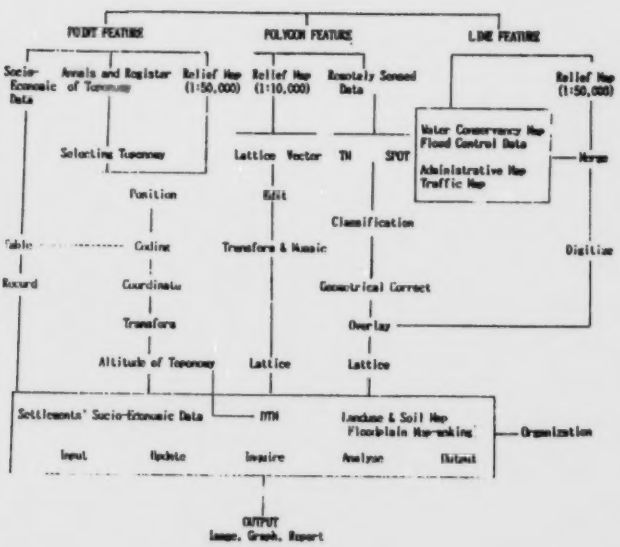
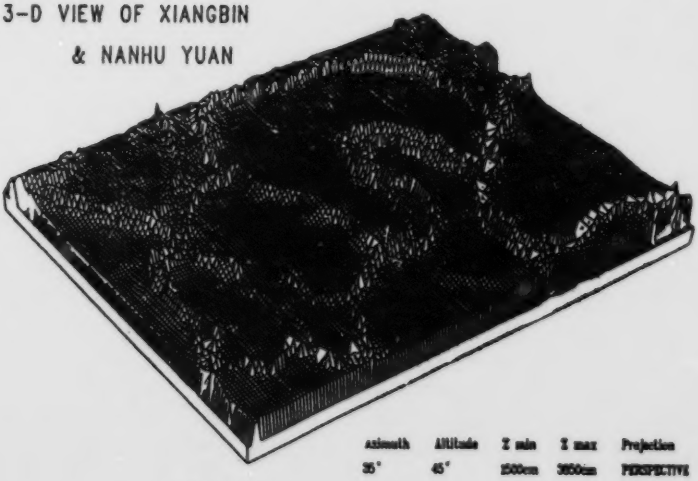


Fig.3 DSA Database

Fig.4

3-D VIEW OF XIANGBIN & NANHU YUAN



Azimuth	Altitude	Z min	Z max	Projection
35°	45°	1500m	3650m	PERSPECTIVE

maintainment and management and crop pattern planning in the dike surrounded areas. The further research is of simulating the dynamic process of flood diverting for each dyke-surrounded area in the region on different flood conditions. The research to these individual DSA will provide with scientific basis for macro management and decision-making of flood control for the whole Dongting Lake region.

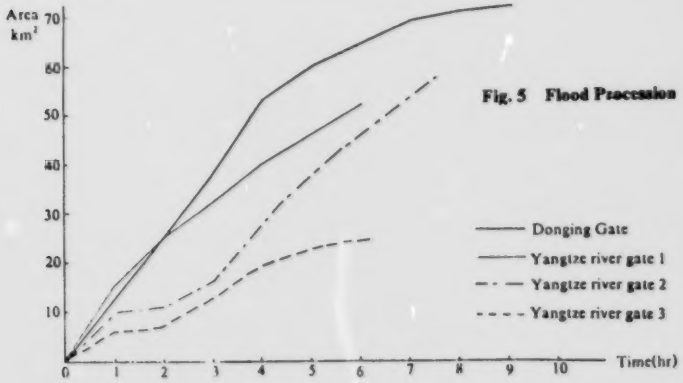


Fig. 5 Flood Procession

(4)The project makes the decision making agencies understand the regulating capability of Dongting lake well. The system has been expanded to Jingjiang reach of Yangtze River. Further works will be of approving the flood control capacity and benefits of the Gezhou Dam and planning Three Gorges Dam in Yantze River. With the help of these database and GIS, it is possible to real-timely monitor the flood condition, evaluate damage and provide information support of decision-making on flood control. At the same time, the more contribution will be made in the next "Five-Year Plan" period on wetlandusc,agricultural development and urban development pattern, esp. on the impact assessment of the planning Three Gorges Dam on swamping of land in Dongting lake region. Further cooperation with Canada is warmly welcomed.

4. Conclusion

It is quite satisfactory that the achievement of the project is a contribution to both the field of application and the sphere of learning. But the present research emphysize the function of flood control and woterlogging prevention. It should be further improved with more functions that applied to flood control for cities,recover planning after the disaster, agriculture base development and oil field construction. These are important.

In order to meet the requirement of planning, managemeat and decision making, the operational capability and practical benefits of the system should be further perfected. Much work should be done on analysis models, expertise software and expert system. It also should introduce the advanced technology of transmission from satellites to ground receiving stations and large screen displaying and so on. The system should be standardized and normalized. Successive effort should be made to realize its operation in Chinese environment.

We have proposed the second successive plan for the project and hope here that IDRC will continue support both in technology and finance. We shall discuss the possibilitcis for broaden bilateral and multi-lateral cooperations with foreign countries.

Acknoledgements

We are especially grateful to Mr. Dijlali Benmouffok(IDRC of Canada),Dr. C. F. Lee(Ontario Hydro, Canada), Mr. Erik de Man(ITC, the Netherlands) for the intensive cooperation we have had for implementing Dongting lake GIS for flood control and management. We thank all project persons for their efforts during project periods.

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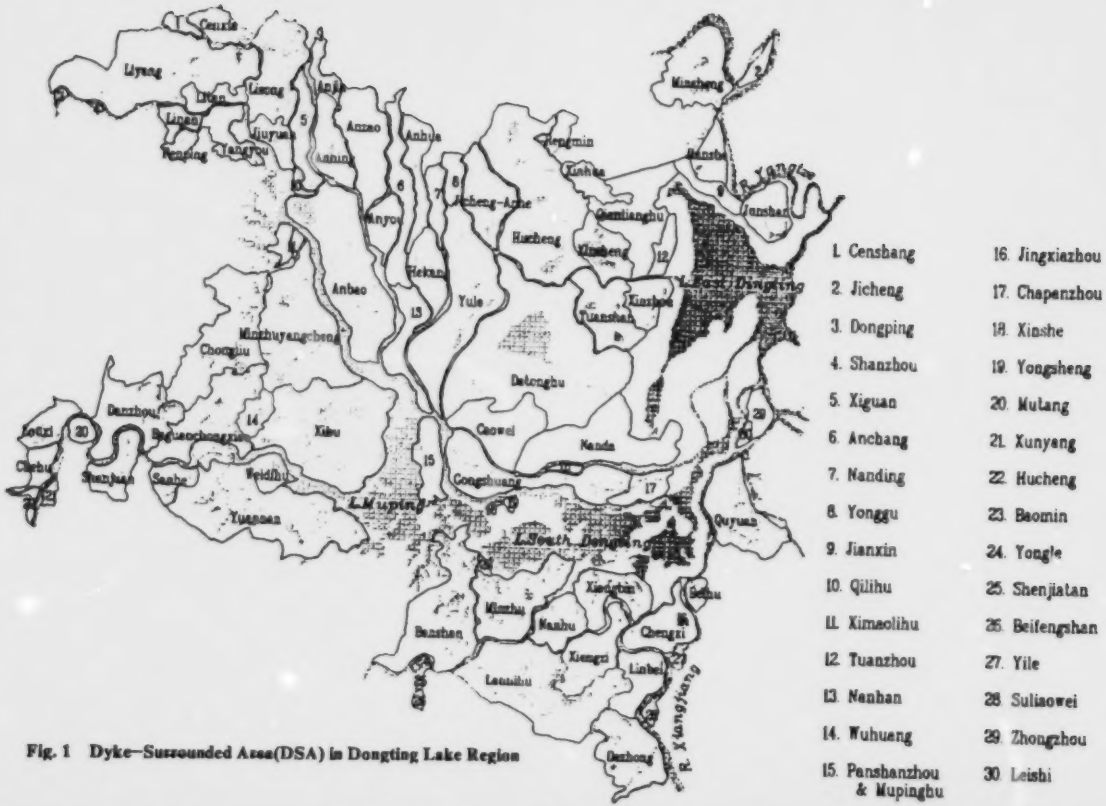

1. Censhang
2. Jicheng
3. Dongping
4. Shanzhou
5. Xiguan
6. Anchang
7. Nanding
8. Yonggu
9. Jianxin
10. Qilihu
11. Ximaolihu
12. Tuanzhou
13. Nanhan
14. Wuhueng
15. Panshanzhou & Mupinghu
16. Jingxiazhou
17. Chapenzhou
18. Xinshe
19. Yongsheng
20. Mulang
21. Xunyang
22. Hucheng
23. Baomin
24. Yongle
25. Shenjiatan
26. Beifengshan
27. Yile
28. Suliaowei
29. Zhongzhou
30. Leishi

Fig. 1 Dyke-Surrounded Area(DSA) in Dongting Lake Region

THE ONTARIO STANDARD LABELLED ROAD NETWORK: INTEGRATION OF EMERGENCY SERVICES AND OTHER USER NEEDS INTO A CONCEPTUAL DATA MODEL

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Abstract

Probably the most dramatic application for digital street networks is in emergency response. Information quality, especially accuracy and currency, is critical. The cost of compiling and maintaining high quality digital networks is substantial, and cannot be borne by emergency services alone. Other potential users of network data may be willing to share the costs if their information needs are satisfied. This points to the need for a standard data model, that (a) addresses the information content requirements of a variety of user groups, and (b) facilitates data exchange. Our study of Ontario's Emergency Health Services and other user groups identified a range of needs. The standard data model presents a broad view of networks at four information levels, for applications such as production cartography, position reckoning, address matching and route optimization. A broad base of users, from commercial cartographers to fast-food outlets, can expect to benefit from network data that conform to this model.

TRACÉS NUMÉRIQUES NORMALISÉS POUR LES RÉSEAUX ROUTIERS DE L'ONTARIO MODÈLE CONCEPTUEL DE DONNÉES RÉPONDANT AUX BESOINS DES SERVICES D'URGENCE ET AUTRES UTILISATEURS

RÉSUMÉ

C'est probablement dans les situations d'urgence que les tracés numériques de réseaux routiers trouvent leur application la plus délicate. La qualité de l'information, en particulier son exactitude et son actualité, devient alors un facteur critique. La compilation et la tenue à jour de données numériques de qualité sur les réseaux routiers comportent des coûts élevés que les services de sécurité ne peuvent seuls assumer. D'autres utilisateurs éventuels pourraient être disposés à partager ces frais dans la mesure où leurs besoins sont satisfaits. Il en ressort la nécessité de mettre au point un modèle normalisé de données qui a) fournisse les renseignements nécessaires à divers utilisateurs, et b) facilite l'échange de données. Notre étude des services sanitaires d'urgence de l'Ontario et d'autres utilisateurs a permis de constater que les besoins sont variés. Le modèle de données normalisées présente une vue d'ensemble des tracés et des quatre types de données qu'ils recèlent, lesquelles peuvent entrer dans des applications telles que la production de cartes, l'estimation de positions, l'appariement d'adresses et le choix des meilleurs itinéraires. Les données conformes à ce modèle devraient pouvoir servir à de nombreux utilisateurs, depuis les cartographes commerciaux jusqu'aux exploitants de restaurant-minute.

Le réseau routier standard de l'Ontario : Intégration des services d'intervention d'urgence et d'autres besoins des usagers dans un modèle de données conceptuel

RÉSUMÉ

Introduction

Un des plus grands avantages d'un système d'information numérique est qu'il permet, en situation d'urgence, l'accès à des données cruciales et leur traitement. La nécessité de traiter de l'information *géographique* dans ces conditions est à peu près universel. L'aide qu'on peut apporter physiquement est tributaire de renseignements sur l'endroit précis de l'urgence, et sur la façon la plus efficace de s'y rendre.

Le service de santé d'urgence (SSU) du ministère de la Santé de l'Ontario est responsable des services ambulanciers pour toute la province de l'Ontario, à l'exception de la région métropolitaine de Toronto. Contrairement aux services de police et de lutte contre les incendies, qui sont gérés par des gouvernements locaux, il doit couvrir toute la province et réagir tout aussi adéquatement face aux urgences survenant dans la métropole qu'à celles arrivant dans le grand Nord.

En 1990, le SSU a commencé à envisager la création d'une base de données numériques sur le réseau routier convenant à la répartition en cas d'urgence, dite pour l'instant Ontario Standard Labelled Road Network (OSLRN), qui constituerait l'autorité en matière de sources de données routières. Puisqu'il nous fallait considérer toutes les routes et rues où peut circuler un véhicule automobile, l'ampleur de la tâche est de toute évidence énorme. Le SSU a rassemblé des experts de divers organismes publics et privés, qui ont étudié la gamme des applications potentielles des données en réseau, ainsi que la possibilité d'échange de données et de partage des coûts. Ce groupe incluait entre autres le Milk Marketing Board et le ministère de l'Éducation, qui dépêchent des véhicules (en l'occurrence des camions de lait et des autobus scolaires) sur les routes de la province, et pour qui l'établissement d'horaires et le routage assistés par ordinateur présentent un intérêt.

Il faut beaucoup de coopération politique et de coordination technique pour réaliser une base de données comme celle de l'OSLRN. Un premier objectif, modeste, serait une définition détaillée d'un modèle conceptuel de réseau routier, qui comblerait les besoins de la plupart des utilisateurs prévus de la base de données. Si le modèle est assez générique pour être adopté par des municipalités, des vendeurs de systèmes et des détenteurs de données, les obstacles techniques à l'échange de données sont virtuellement levés. Le groupe a chargé les auteurs de concevoir le modèle de données de l'OSLRN. La définition formelle du modèle figure dans d'autres documents (Tomlinson Associates, 1991); le présent aborde la question sous l'angle des applications.

1. INTRODUCTION

One of the most compelling justifications of a digital information system would be the need to access and process crucial data under pressure of an emergency. The need for *geographic* information processing in these situations is almost universal. The physical delivery of assistance requires information on the precise location of the emergency, and the most effective route to the scene.

The Emergency Health Services (EHS) branch of the Ontario Ministry of Health is responsible for delivering ambulance service to all of Ontario except Metro Toronto. Unlike police and fire, which are administered by local governments, EHS must deal with the entire province, and deliver service equitably both in the Golden Horseshoe megalopolis and in the remote north.

In 1990 EHS began to explore the creation of a digital road network data base suited to emergency dispatching, tentatively termed the Ontario Standard Labelled Road Network (OSLRN). It would be an authoritative source of current road data for the province. Given that a road in this discussion is any highway or street designed for a motor vehicle, the magnitude of this task is clearly enormous. EHS assembled experts from several public and private bodies, to study the range of potential applications of network data, and to examine the possibilities of data exchange and cost sharing. The group included members such as the Milk Marketing Board and the Ministry of Education, who schedule vehicles (milk trucks and school buses respectively) along provincial roads, and have an interest in computer assisted routing and scheduling.

It requires a high order of political cooperation and technical coordination to realize the OSLRN data base. A first, modest objective would be a detailed definition of a conceptual road network model, that would address the needs of most of the anticipated users of the data. If the model was sufficiently generic that it could be adopted by municipalities, system vendors and data custodians, then the technical barriers to data exchange would be largely eliminated. The group commissioned the authors to design the OSLRN data model. The formal model definition is contained in other documents (Tomlinson Associates, 1991); this paper approaches the matter from an applications viewpoint.

2. APPLICATIONS OF ROAD NETWORKS

The SLRN design process began by identifying the principal potential users of medium scale (1:50,000 to 1:10,000) centreline network data, and the information sets required by each. A centreline (as opposed to kerbline) data base represents a street by a single polyline running approximately through the centre of the street. Kerbline files are useful only for large scale (larger than 1:10,000) municipal type applications.

Present and potential users of centreline files include cartographic firms, municipalities (scheduling of garbage collection, street cleaning and snow ploughing), utility firms, wholesale distributors running truck fleets (soft drink companies, supermarket chains), political parties, market researchers, direct mail companies and the post office, all home delivery (pizza, newspaper, department stores), and emergency response units. There are four basic application areas:

Cartography (base maps). Medium scale topographic sheets usually show roads only in terms of positional alignment, with the class of road sometimes indicated by line symbology. Primary highways are usually annotated, whereas urban streets are not named. This level of information serves only to indicate the existence of a network.

Basic reckoning and navigation (street maps). From the viewpoint of everyday applications, a more useful network representation is the one found in mass-market street maps. By simple visual correlation with landmarks, a disoriented user can gather enough information to determine the general location of a street, e.g. Yonge Street, and can trace a suitable route to a destination.

Address matching. Basic navigation as described above is sufficient for occasional users of address data. Professional users, such as emergency crews, delivery personnel and market researchers, must usually be able to geocode an address, e.g. 127 Yonge Street, to block face resolution. In other words, they require coordinates for the address, that are accurate within no more than a few hundred metres. In applications such as school busing, it is important to know on which side of the street a given address falls. Specialized map books and city guides may print civic numbers at major intersections; detailed address ranges and coordinates for block faces are available in digital form for major Canadian cities, from Statistics Canada's Area Master Files (AMFs).

Routing and scheduling. In a digital environment, network data can be used to determine optimal paths, and to schedule flows with capacity constraints. This application requires topological networks, in which the relationship of each road to each of its intersecting neighbours is explicitly specified, and impedance measures (e.g. distance) are attached to each road segment. Rural routing is usually straightforward, since congestion and traffic control are not significant issues. On the other hand an urban routing system must ideally consider stop signs, traffic light programming and instantaneous congestion measures, in determining the impedance of a route. The cost of providing current data on this scale is prohibitive, hence one must be realistic in one's expectations of the scope of automated routing.

A network model should address each of the above applications, and should also be designed to facilitate error detection and correction, and update.

3. A BRIEF REVIEW OF DATA MODELS

Digital street data have been in circulation for several years now, notably through the AMF in Canada, and the US Census's DIME and TIGER files. These data bases were originally designed to assist census enumerators, and the data models may not be well suited to popular modern applications such as those detailed above.

DIME/TIGER: The DIME files were designed to store urban polygons (city blocks) and streets simultaneously in a unified data structure. In the attempt to maintain topological integrity of the polygons, DIME viewed streets essentially as polygon boundaries. When two streets crossed paths, there was no distinction between traffic intersections and non-grade crossings such as overpasses. TIGER, designed for the 1990 US Census, is a major reconstruction of the original DIME structure. Yet in both cases the primary entity is a road segment between two intersections. A major road, such as Yonge Street in Toronto, is therefore fragmented into

numerous short links. In general a fragmented model contains data redundancies and is inefficient for both storage and access — although performance ultimately depends also on the data structure and implementation.

AMF: The Area Master File treats a street as a single continuous entity, listing intersecting streets as they occur along its path. Attributes such as address ranges are logically attached to each segment.

The crucial problem common to AMF and DIME/TIGER is that the building block is the urban block face (Statistics Canada has recently improved the AMF structure; it is now based on topological chains). Attributes associated with the network, such as pavement condition, the number of lanes, or the location of point landmarks, must therefore be coded with the block face (or topological chain) as the basic unit of resolution. This is clearly inadequate, and especially where block faces are long, this representation can result in serious analytical errors. Alternately, the resolution must be improved, and each street must be broken wherever *any* attribute changes. The result is a file that is disproportionately large, given its information content.

4. THE SLRN MODEL

The SLRN model is reactive rather than proactive, in that it is a response to the way networks are conceived and used, rather than a prescription for instituting radically different methods. The model is built on the concept of "dynamic segmentation," that has recently been discussed in the GIS literature. A person normally has a mental construct of a road as a logical and coherent entity — this is equally true of neighbourhood crescents as it is of cultural landmarks such as Yonge Street. The SLRN maintains the integrity of the road, and attaches auxiliary information such as address ranges and intersections when appropriate.

The model is designed to address all the four principal application areas of street networks identified above, namely, cartography, position reckoning, address matching and routing. Accordingly, there are four information levels in the model.

Level 1

The term **thoroughfare** is used to describe the general class of motorable surfaces in a network. The basic SLRN entity is a **road**, a continuous length of thoroughfare which is distinguished from the rest of the network by virtue of having a defined beginning and end. The model is flexible as to how the beginning and end of the road are defined. Consider for example Toronto's Yonge Street. It runs from Queens Quay in southern Toronto to Steeles Avenue, the northern limit of the city (Figure 1). A data base for Metro Toronto may choose to define Yonge Street as a single entity from Queens Quay to Steeles, or may break it into say two sections, the first from Queens Quay to Eglinton, the second from Eglinton to Steeles. The partitioning would usually be designed to correspond with existing spatial divisions or "tiles" in the data base, such as map sheet or civic ward boundaries. In an extreme case the road may be fragmented into several hundred block faces, but that would clearly negate the advantages of the SLRN model.

Points along the road are addressed in terms of their **offsets**, i.e. their distance from the beginning point. The name of the road is not stored at Level 1, yet the fact that it is continuous, and connects a defined pair of end points, does lend the road an implicit identity.

From an applications viewpoint, Level 1 data are in effect coordinate chains for unlabelled cartographic plotting such as in topographic maps. Since the road is a continuous entity, symbology and line weight are constant for the entire stretch of road.

Level 2

The second information level is the labelled road. In reality a road may have an alias, or a physically continuous road may have more than one name, either along its entire course or in different stretches. There may be more than one road with the same name (e.g. King Street), usually assigned by different municipalities.

One or more road names may be attached to any stretch of a SLRN road, each stretch being defined by a start-offset and end-offset. Each name record has fields for the naming authority and the civic numbering system. A Lot-and-Concession nomenclature may therefore coexist with a civic addressing system on the same physical road.

Level 2 information is sufficient for automating production of the network layer (including annotation associated with the network) in street maps. In a production environment one may need to store road class information (e.g. primary or secondary highway; major or minor urban street). The model does not explicitly provide for a road class field, since the assignment of classes is ultimately subjective. If the road is formally assigned a class by the naming authority (e.g. The King's Highways in Ontario), this applies to the entire section of road covered by that name, and could be indicated in a Level 2 name field without violating the fundamental character of the model. On the other hand, if class is a judgement of the importance of the road, based on the number of lanes, traffic capacity or average speed, this information would often vary along the course of the road, and is better stored as an Extended Object (see below).

Level 3

Civic address data are usually made available as block face address *ranges*. It is a simple linear interpolation problem to estimate the coordinates of say 127 Yonge Street, given coordinates for 100 Yonge Street and 200 Yonge Street. With long block faces, however, the accuracy of interpolation relies on the questionable assumption that addresses are assigned in regular linear fashion. Accuracy would be improved if coordinates were known for some intermediate addresses in a block; the traditional model does not allow for these to be stored.

The SLRN introduces the concept of a **correspondence**. This is simply a logical mapping of a random offset to its known civic number. By departing from the block face as a unit of resolution, this structure permits correspondences anywhere along the road. Since correspondences may easily be established at beginnings and ends of blocks, the SLRN model accommodates conventional address range data.

Note that interpolation between correspondences, say for 127 Yonge Street, yields the *offset* of 127 Yonge. The coordinates of that address are found by subsequent interpolation along the coordinate chain.

Level 4

Although the above levels contain enough information for many useful applications, they store no topological information, and roads may begin and end at arbitrary points. Routing applications require connectivity data at intersections. This can sometimes be inferred from coordinate chains, but since bridges, flyovers and other non-grade intersections complicate the network fabric, the information must be stored explicitly.

In a Level 4 SLRN, each time an intersection is encountered over the course of a road (the **primary** road), the offset is recorded, along with the identifier of the intersecting, **secondary** road. Since the secondary road may cross the primary road more than once, the offset along the secondary road is also stored at each intersecting point. Where two roads cross paths at non-grade intersections, i.e. neither is physically accessible from the other, an intersection is not recorded.

This is sufficient information to construct connectivity tables for simple routing applications. Moreover, with this data model, the procedures that generate connectivity tables can easily be adapted to extract a generalized network (i.e. selected routes, such as major arteries) for macro-level analysis.

The impedance associated with each network link may in the simplest case be calculated as a function of the offset. This may not be appropriate in hilly landscapes, where the offset distance (which is measured along the digitized coordinate chain) may differ substantially from odometer distance. In such cases the impedance, whether odometer distance, average driving time or any other measure, may be recorded as an attribute field (see Associated Objects, below).

Associated Objects

The SLRN model does not recognize any features in the landscape (e.g. gas stations, time zone boundary lines, parks), except to record their interaction with the network. In other words, the SLRN is not a generic spatial data model, and is not designed to store random points, polylines or polygons. There are definable relationships between these geometric features and a network: any point in space can be associated with the *point* on the network that is closest to it; a polyline intersects the network at one or more *points*, or rarely, a line; and a polygon intersects a network over a length of a network *line*.

Accordingly, the SLRN defines **point objects** and **extended objects**. A point object (e.g. gas station, time zone boundary) is an entity associated with a *point* on the network, identified by the road ID and the offset of the point along that road. An extended object (e.g. park) is an entity associated with a *section* of one or more roads, identified by the road IDs, and a start-offset and end-offset along each road. Point objects and extended objects are optional with all levels of SLRN.

Data Revision

The model design explicitly recognizes that coordinates need to be updated periodically, and often selectively. The most likely sources of new coordinates are GPS, photogrammetry, new surveys, and transformations such as NAD27-NAD83 conversion. Quality improvements may take the form of revised or higher-precision coordinates for established points (such as major intersections); better resolution on curves, introducing new points; or additions or deletions of roads or segments of roads.

Additions and deletions are straightforward. For the other two forms of enhancement, update is achieved by first identifying **tie points**, usually all intersections, for which locations are known in both the outgoing and new data bases. Points other than tie points in the outgoing data base will be (a) intermediate nodes in chain definitions, stored as coordinates; and (b) correspondences and associated objects, stored as offsets. Old coordinate chains (a) are discarded and simply replaced by the new versions. Offsets (b) are first converted to coordinates, relative to the tie points in the *outgoing* data base; new offsets are then derived, relative to the new tie points. Offsets will almost always increase with higher resolution data.

5. CONCLUDING REMARKS

The SLRN was designed in early 1991, and is now being circulated among standards agencies in Canada and the United States. It is possible that terminology may be revised, and that other changes may be made in response to public comment. This paper is a brief, informal description of the model. The reader is referred to the original document for technical details.

The apparent shortcomings of the SLRN model are largely intentional. The model deals with the *physical*, not legal aspects of the network. If a road is physically inaccessible from another, as in the case of a simple overpass, the SLRN model does not consider them connected. If the roads intersect at grade, the SLRN blindly records the intersection. There is no provision in the model to indicate whether or not turns are permitted. The reason for this is not technical — Level 4 can easily be broadened to accommodate stop signs and turn tables — but a matter of reality. Legal permissions change daily, and it is rarely that one finds sufficiently current data. At present there is little demand for such information.

Similarly the model can be adapted to store dynamic congestion data. A few cities around the world, including Toronto, have built sensors into the pavement of freeways and major arteries, to measure traffic volume and velocity. There is speculation that congestion and positional information could be continuously broadcast to on-board vehicle navigation assistance (VNA) systems, over radio frequencies. This is an expensive proposition, and it will probably be several years before any city implements it on a large scale. Since the SLRN is designed to be reactive rather than revolutionary, detailed model refinement, if required, should be delayed until the direction of these technological developments is clear.

The above examples illustrate the scope and intent of the SLRN model. It is a data *model*, not a data structure. It merely organizes network data into information classes; beyond that it is intended to be a generic and flexible framework, deliberately avoiding specifications on formats, fields and data quality matters. It thus provides a technical foundation for orderly data exchange.

The political dimensions of digital data exchange remain to be resolved. There are undoubtedly costs involved for a data supplier or data user to equip itself to trade digital information. On the other hand, considering that data gathering and input represent the bulk of operating costs in a GIS, the savings on redundant efforts in these areas will easily justify the investment in SLRN compatibility.

The Ontario Ministry of Health and the Ministry of Natural Resources recently embarked on a cooperative pilot venture to pool resources, to exchange data and to develop a Level 3 network

for the Ottawa area. Although no software has yet been written around the SLRN model, the SLRN information content standards are temporarily being accommodated within existing systems, albeit at some cost in computing efficiency. The MOH-MNR project involves enhancing MNR's OBM (Level 1) street data with the information fields specified in Level 3, as required by MOH. Needs such as these drove the development of the model; efforts such as these will ultimately establish its usefulness.

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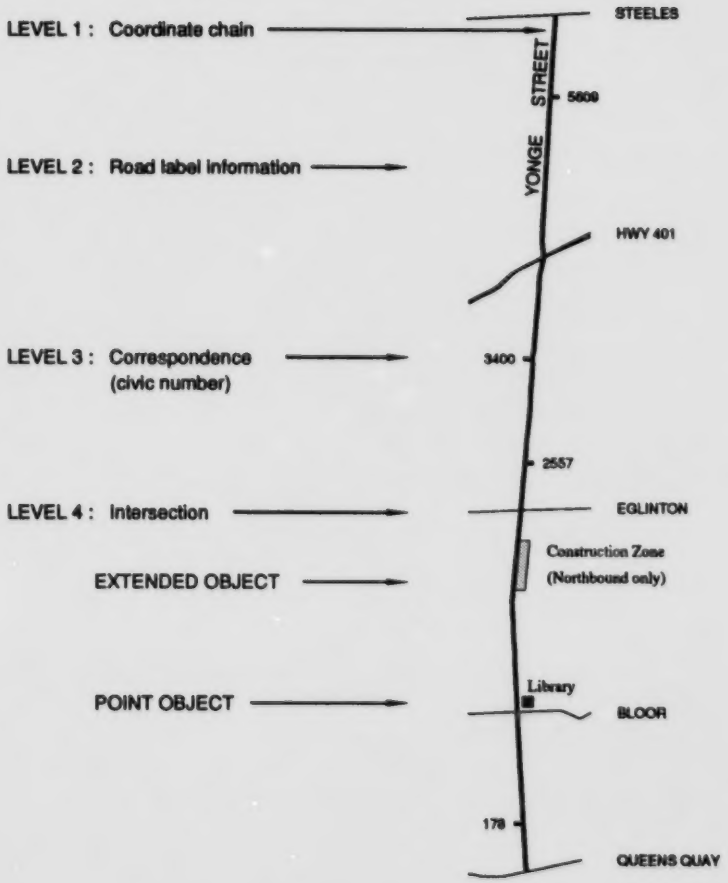

Figure 1: SLRN representation of Yonge Street, Toronto

GIS and Mathematical Models for Regionalization of Land use Planning in China

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ABSTRACT

China is a large country both in land and in population. But it is a small country both in per capita land and in per capita farmland. In order to use land economically and beneficently land use planning has been designed by the government in China this year. Regionalization of land use planning is a part of it.

This paper discusses how to apply GIS and mathematical models for regionalization of land use planning in China.

Firstly, the data base both spatial data base and attribute data base has been established with GIS, including 32 items such as the areas of farmland, orchard forestry, grass land, urban and town, traffic land, unused land, population, economi output etc. in 2370 countries and cities. And 6 basic overlays covering all the country.

Secondly, the mathematical models have been set up in GIS, including 1. classification models; 2. regional multiple evaluation models; 3. regionalization models.

Finally, 10 first level regions and 33 second level subregions are identified in this system. The different policies of land use in the next ten years have been made according to the regions.

SIG et modèles mathématiques pour la régionalisation
de la planification de l'utilisation des terres en Chine

RÉSUMÉ

La Chine est un grand pays par sa superficie et sa population. Pourtant, elle dispose de peu de terres, et de terres agricoles, par habitant. Pour utiliser ces terres de manière économique et rentable, le gouvernement de la Chine a décidé cette année de procéder à une planification de l'utilisation des terres, qui sera régionalisée.

Le présent document discute des application du SIG et des modèles mathématiques à la régionalisation de la planification de l'utilisation des terres en Chine.

D'abord, la base de données, tant du point de vue spatial que de celui des attributs, a été réalisée avec un SIG; elle comprend 32 rubriques, comme les superficies des terres agricoles, des vergers, des forêts, des prairies, des zones urbaines, des zones de circulation, les terres inutilisées, la population, la production économique, etc. pour 2370 villes et comtés. Six cartes de base couvrent tout le pays.

Ensuite, les modèles mathématiques ont été établis en SIG, dont : 1) les modèles de classification, 2) les modèles d'évaluation multiple régionale et 3) les modèles de régionalisation.

Enfin, 10 régions de premier niveau et 33 sous-régions de second niveau sont identifiées dans le système. Les diverses politiques d'utilisation des terres au cours des 10 prochaines années seront élaborées selon les régions.

ESTIMATION AND ORGANIZATION OF SPATIO-TEMPORAL DATA

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Abstract

The management and processing of spatio-temporal data is of major concern in any geographic database. Effective and efficient handling of time-dependent data allows for the determination of past and present absolute geographic states and the forecasting of future states as well. The changes between two or more absolute states can also be determined. Various estimation modes for time-varying data are presented and discussed with respect to their efficiency in storage, retrieval and updating of data. The temporal aspect in the relational data model is examined and the organization of the data using this model is illustrated with an example.

ESTIMATION ET ORGANISATION DE DONNEES SPATIO-TEMPORELLES

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Résumé

L'administration et le traitement de données spatio-temporelles est d'un intérêt majeur pour les banques de données géographiques. L'utilisation efficace de données spatio-temporelles permet de déterminer l'état géographique absolu passé et présent, et de prévoir des états futurs. Les changements entre deux ou plusieurs états absolus peuvent aussi être déterminés. Divers modes d'évaluation de données dépendantes du temps sont présentées et discutées selon leur efficacité à conserver, récupérer et mettre à jour les données. L'aspect temporel du modèle relationnel est étudié, et l'organisation des données, selon ce modèle, est illustrée grâce à un example.

1. INTRODUCTION

Frequent and continuous changes in the geographical domain, high temporal resolution and vast amounts of data, requests for updated and valid information for knowledge-based decision-making and management, needs for global monitoring, and assessment of the changes in the environment are some of the issues requiring a holistic and systematic approach in order to handle the temporal dimension of the geographic data.

The incorporation of the time factor allows for the understanding of the evolution of geographic elements, and focuses on geographic processes through the determination and representation of interactions among space, time, attributes and procedures. Handling of time-dependent geographical data involves the following general stages:

a) the storage and retrieval mechanisms (temporal databases, organization and estimation processes of temporal data, access methods for temporal data), and

b) the development of effective spatio-temporal data models (structures, methods, procedures, analysis functions, processing, visualization).

2. BASIC REQUIREMENTS FOR TIME-DEPENDENT DATA

Estimation methods for time-varying geographical information are approaches that determine spatio-temporal data in the best possible (optimal) way. An estimation process deduces information utilizing prior knowledge on initial conditions, new data and known relationships to determine the desirable outcome. At the same time, an estimation process provides accuracy estimates and reduces errors and uncertainty to a minimum. In the spatio-temporal domain the following need to be defined:

1) the absolute states (time snapshots) of the geographical domain, which provide a complete picture of the geographical status at various specific and discrete time points;

2) the comparison between absolute states of the geographical domain, which provides the changes that occur over a period of time between two or more time snap-shots;

3) the transitional procedures, which provide the reasons for the changes, that is the manner in which an absolute state of the geographical domain is transferred to another one over a period of time.

These aspects are essential to meet the needs for handling time-dependent geographical data, as they provide answers to basic questions, such as: "what is the current situation", "what was the situation at a past time t", "what are the differences between the time snapshot at t_1 and the time snapshot at t_2", "what caused the changes", "how have the changes occurred", and "what will be the situation in the future time t_f under certain conditions". Therefore, a temporal geographical system system must be capable of fulfilling the following basic requirements:

1) the most recent geographical state must be readily available. This requires the estimation of the desirable current geographical data based on all past states and on all additional current data which are available at the instant of query (filtering mechanism).

2) the ability to reconstruct past geographical states and to recreate the evolution of past processes and events, when the time-queries fall within the span of the up-to-date available spatio-temporal data (interpolation and smoothing mechanisms).

3) the ability to forecast future states and simulate future developments in the geographical domain, based on present information, state dynamics and future scenarios must be available (prediction mechanism).

3. ESTIMATION METHODS FOR TIME-DEPENDENT DATA

The determination of information about absolute states, changes and transitional procedures utilizing the above mentioned estimation mechanisms can be done according to the following estimation modes. Certain parts of these methods have been developed based on the ideas of Langran and Chrisman, 1988.

3.1 Static mode

In the static mode, the absolute individual states are stored in consecutive time-ordered sequence. The most recent state is readily available. The data is organized and stored in the form:

$$S_0, S_1, S_2, ..., S_c$$

where S_i is the individual time-snapshot

and $i = 0, 1, 2, , c$, with 0 indicating the initial state and c the current state.

It is therefore a series of concatenated time snap-shots of the geographical domain. All elements comprising each state carry the same time-stamp. The data structure of the static

mode allows the direct determination of the status of a geographical state at discrete and specific instants time. Unless, the sampling time points are taken at frequent time intervals, it is difficult to sufficiently monitor the spatio-temporal paths of the geographical data.

The comparison between states to determine changes which occur within a given time interval will be a tedious task. For vector types of data, overlay algorithms can be used to define the composite layer of two or more temporal layers, and to detect and locate changes. For raster types of data a pixel subtraction operation can be used to assess the degree of change that has taken place between pairs of co-registered raster maps or images of geographical states. Additionally, the transaction logs of the transitional procedures need to be examined in order to have a complete comparison between two states.

Although storage cost decreases while storage capacity increases, the storage of all temporal states is also a concern. No matter the degree of changes, a great portion of unchanged data will have to be stored every time an updated state is produced. This creates an unnecessary storage redundancy. The procedures of updating the master database (MDB) in the static mode are illustrated diagrammatically in figure 3.1.

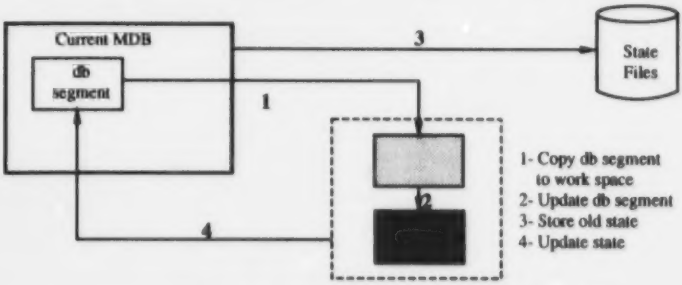

Figure 3.1: Temporal estimation - static mode

3.2 Differential mode

In the differential mode, the initial state and the various differential files representing the changes from one state to the next are stored. The stored data will be:

$$S_0, \Delta S_1, \Delta S_2, \ldots\ldots, \Delta S_n$$

where S_0 is the initial state, ΔS_i are the recorded changes over time, and
i=1, 2, , n indicates that changes occur at time 1,..., n between states i and i-1.

The disadvantage of this approach is that the current state is not readily available. Of course it can be determined indirectly as:

$$S_n = S_0 \cup \Delta S_1 \cup \Delta S_2 \cup ..... \cup \Delta S_n = S_0 \cup \sum_{i=1}^{n} \cup \Delta S_i$$

but that requires time and a lot of processing.

The differential mode provides an answer to the query "what is the state at time t", for example,

at $t = 2$ the state $S_2 = S_0 \cup \Delta S_1 \cup \Delta S_2$,

and to the query "what are the changes between t_i and t_j", for example the changes between t_1 and t_3 can be determined as:

$$\Delta S_{1-3} = S_3 - (S_1 \cap S_3) \implies \Delta S_{1-3} = \Delta S_2 \cup \Delta S_3$$

For the the determination of the changes, the required processing (fig. 3.2) is less than that required in the case of absolute states (static mode). In the latter, the entire state files need to be merged and compared to produce the differences, while in the other only the differential files need to be retrieved. The involved differential files should have independent topological structure, that is they must not depend on the initial state. This is necessary for the determination of information about the changes within the 'delta' files and for the existence of error-checking mechanisms (Armenakis, 1991). Thus, this structure provides direct answers to a query such as "how much does an area change between t_0 and t_1". The storage requirements for the differential mode are minimal.

Besides the step by step approach of the differential method, there is also the so called accumulated differential approach (Langran, 1988). In this alternative, the individual total differences between the initial (or current) state and the states under consideration constitute the differential files. Thus, instead of moving step by step from one state to the next (or previous) by adding the difference, we leap from the initial (or current) state to any state. This approach is expressed as:

$S_c = S_0 \cup \Delta S_{0-c}$, with t_c refering to current state and t_0 refering to any initial state.

While the accumulated differential mode may duplicate elements stored in the differential

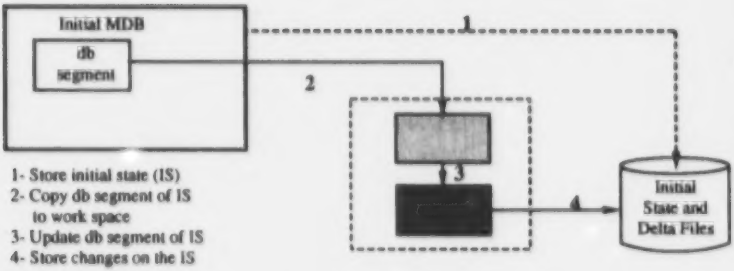

Figure 3.2: Temporal estimation - differential mode

files, it also allows the direct determination of the state of interest without state-to-state hopping. However, the estimation of the changes between any two or more states still requires extra effort.

3.3 Sequential updating mode

The sequential updating mode attempts to reduce some of the disadvantages of the static and differential approaches. Its objective is to maintain the current state readily available, while providing mechanisms for spatio-temporal navigation using minimum storage and processing cost. Two types of sequential updating processes can be distinguished.

3.3.1 Sequential differences updating mode

This approach is based on a continually updated state. That is, whenever a change occurs it is immediately incorporated into the current state, and it stored as a time-indexed differential file. The process is expressed in general terms as:

$$S_c = S_{c-1} \cup \Delta S_{c-1,c}$$

At each update cycle of the state of the geographical domain, the corresponding difference file is stored with the appropriate reference pointer (index). Thus, the stored elements are:

i) the current state file: S_t

ii) the difference files: $\Delta S_{t-1,t}, \Delta S_{t-2,t-1}, \ldots\ldots, \Delta S_{1,2}, \Delta S_{0,1}$

The approach is quite attractive as the present state is there when needed and there is no redundant storage of data. In addition, it is easy to determine the changes which occured

between time periods, and it is possible to indirectly reconstruct any previous geographical situation. Figure 3.3 illustrates this estimation mode.

It is possible to avoid storing the delta files if the space-time composite approach (Langran and Chrisman, 1988) is followed. In this context, the time factor characterizing the changes is attached to each geographical unit as a temporal attribute. A mechanism

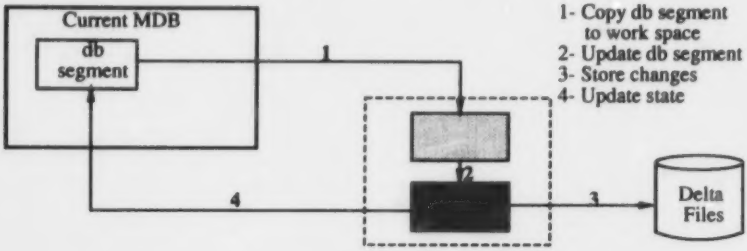

Figure 3.3: Temporal estimation - sequential differences updating mode

for retroversion is then required to allow travelling through the history of the attributes and to reconstruct any time state by selecting and building the units with the same time reference.

3.3.2 Sequential components updating mode

This is similar to the previous approach. Once again the current state is continually updated as changes occur. The difference between these two approaches is that instead of keeping the changes (delta files), which may turn out to be impractical, the object-units of the geographical domain that existed in the previous time period are stored. This means that each unaltered geographical domain within a time interval consists of a set of geographical components. When time affects one component, its until now current status is superseded by the updating one, while the immediate previous object is stored using link mechanisms and temporal indexing.

The sequential components updating method for estimating spatio-temporal information is shown in figure 3.4. This approach offers immediate access to the current state, expands horizontally and vertically, reconstructs past states by substituting current components for the previous versions, determines the changes by comparing only the components that have been changed (comparison operations at parts of the database), and does not

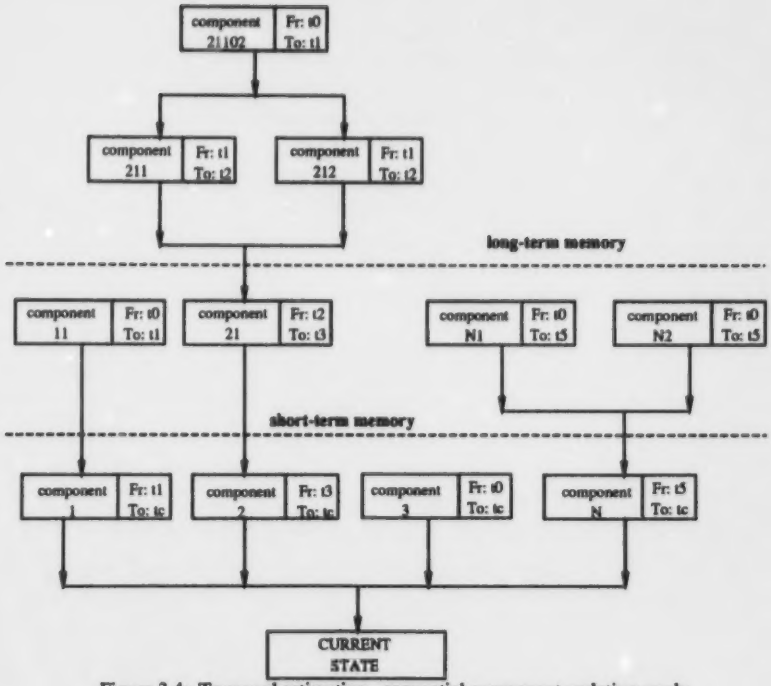

Figure 3.4: Temporal estimation - sequential component updating mode

duplicate unchanged components. This scheme of spatio-temporal modelling of geographical space can adapt to the upcoming object-oriented technology, (Egenhofer and Frank, 1989).

4. TEMPORALITY IN THE RELATIONAL DATA MODEL

The current databases at the Geographical Services Division are of the relational type. Therefore, the relational model for expressing temporal data is being examined at this initial stage due to its operational status. Temporal relations can be represented at the relation, attitude and tuple level (Langran, 1988 & 1989; Navathe and Ahmed, 1989). The relation-level time-stamping is similar to the "snapshot" approach. Every time an attitude or an entity changes a new relational table is created. The replication of entire tables, even with small changes, faces similar problems to the static mode of temporal

estimation. The attribute-level time-stamping tackles the problem of the redundancy of the "snap-shot" relational tables. However, it requires variable length records, which pose problems to the manipulation of the non-normalized relations. In the tuple-level time-stamping the relational table is extended by appending new tuples each time an attribute or an entity changes. It is obvious that the table-rows grow proportionally to temporal changes. Access to the relations is obtained through a paired key comprising the time invariant element (e.g., entity) and the time-stamping attribute. Explicit description of the representation of temporal relations can be found in Armenakis, 1991.

4.1 Tuple-level time-stamping with temporal links

The tuple-level time-stamping with temporal links is based on the principle that the current state should be readily available, while effective linkages are maintained to permit tracking of historical data (Lum et al., 1984). In this approach, present and past data are stored separately. The historical data is sorted in descending temporal order. The data of the current state table is linked to its immediate previous status contained in the historical table. The historical data is also chained with its predecessors within the history table. The consecutive temporal connections of elements allow for the tracing of the historical phases of an entity without causing additional burdens to the operations of the present state. An simplified example of a road network map and its evolution during three time periods has been created to demonstrate this approach (fig. 4.1, Table 1). This structure carries the geometry and attributes through time if no changes occur. Only the basic information about the changes is required and is included (yes/no/new). The historic tracking is also possible for the recreation of states at specified time periods using history link keys. It is a hybrid approach as it contains elements from the sequential components updating mode, the tuple-level time-stamping with temporal links, and, the tuple level time-stamping.

The 1990 present edition, the changes from the 1980 edition and the link to the past are given in Table 2. Table 2 is linked to Tables 3 and 4, which contain the current geometry and attribute information. The geometric historic information of the states and their links to the present (Table 5) and past (Table 6) are given in Table 5. The entities in the past states are organized in descending chronological order. Similarly, the historic information of the past attributes is shown in Table 7, with links to present (Table 2) and to Table 8 for the non-present attributes.

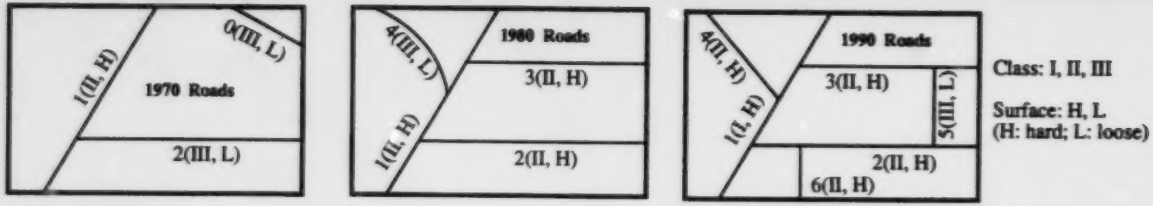

Figure 1: Absolute states of the road network

????? - 1970

EID	Link to geometry	Road class	Road surface	Changes in geometry	Changes in attributes
0	LG0	III	loose	new	new
1	LG1	II	hard	new	new
2	LG2	III	loose	new	new

1970 - 1980

EID	Link to geometry	Road class	Road surface	Changes in geometry	Changes in attributes
1	LG1	II	hard	no	no
2	LG2	II	hard	no	yes
3	LG3	II	hard	new	new
4	LG4	III	loose	new	new

1980 - 1990

EID	Link to geometry	Road class	Road surface	Changes in geometry	Changes in attributes
1	LG1	I	hard	no	yes
2	LG2	II	hard	no	no
3	LG3	II	hard	no	no
4	LG4	II	hard	yes	yes
5	LG5	III	loose	new	new
6	LG6	II	hard	new	new

Table 1: Characteristics of the road network

Table 2: Present state

1980 - 1990						
EID	Link to present geometry	Link to present attributes	Changes in geometry	Geometry was key	Changes in attributes	Attribute was key
1	LPG1	LPA1	no	G10	yes	A10
2	LPG2	LPA2	no	G20	no	A20
3	LPG3	LPA3	no	G30	no	A30
4	LPG4	LPA4	yes	G40	yes	A40
5	LPG5	LPA5	new	*	new	*
6	LPG6	LPA6	new	*	new	*

Table 3: Present geometry

1980 - 1990	
Link to present geometry	Present Spatial Data
LPG1	Xs , Ys , Zs
LPG2	Xs , Ys , Zs
LPG3	Xs , Ys , Zs
LPG4	Xs , Ys , Zs
LPG5	Xs , Ys , Zs
LPG6	Xs , Ys , Zs

Table 4: Present attributes

1980 - 1990		
Link to present attributes	Class	Surface
LPA1	I	hard
LPA2	II	hard
LPA3	II	hard
LPA4	II	hard
LPA5	III	loose
LPA6	II	hard

Table 5: States of past geometries

Geometry History Key	EID	Link to past geometry	Changes in geometry	From	To	Geometry was key
G10	1	*	no	1970	1980	G100
G20	2	*	no	1970	1980	G200
G30	3	*	new	1970	1980	*
G40	4	LHG4	new	1970	1980	*
*	0	LHG0	new	*	1970	*
G100	1	*	new	*	1970	*
G200	2	*	new	*	1970	*

Table 6: Past geometries

Past geometries			
Link to past geometries	Spatial data	From	To
LHG4	Xs , Ys , Zs	1970	1980
LHG0	Xs , Ys , Zs	*	1970

Table 7: States of past attributes

Attribute History Key	EID	Link to past attribute	Changes in attribute	From	To	Attribute was key
A10	1	LHA1	no	1970	1980	A100
A20	2	*	yes	1970	1980	A200
A30	3	*	new	1970	1980	*
A40	4	LHA4	new	1970	1980	*
*	0	*	new	*	1970	*
A100	1	*	new	*	1970	*
A200	2	LHA2	new	*	1970	*

Table 8: Past attributes

Past attributes				
Link to past attributes	Class	Surface	From	To
LHA1	II	hard	1970	1980
LHA4	III	loose	1970	1980
LHA2	III	loose	*	1970

The applicability of this practical example is under investigation. As traditional RDBMS do not provide the tools for maintaining the time-stamps, new software needs to be develop to allow the reconstruction of the history (Lee, 1989). In addition, the capabilities of the extensible databases, (e.g., POSTGRES; Stonebraker and Rowe 1986), which support the handling of multi-temporal versions of objects need to be examined.

5. CONCLUSIONS

The temporal dimension of spatial data is an essential component of dynamic GISs. It allows for tracking the history of the data, evaluating their trends, and forecasting future states. Optimal estimation and organization of time-dependent data will lead to efficient management and processing of multi-temporal data and the development of temporal databases. It will also improve the studies on trend analysis, dynamic modelling and mapping, and forecasting of geographic data.

6. ACKNOWLEDGEMENT

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INTEGRATED PROCESSING WITH IMAGE ANALYSIS AND GEOGRAPHIC INFORMATION SYSTEMS IN A COMMERCIAL CONTEXT

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ABSTRACT

Integrated processing with image analysis and geographic information systems (GIS) is possible with today's technology. A growing number of companies and government agencies in Canada and the United States are developing and marketing this type of integrated processing. These applications involve enhancements, classification, and geocoding of LANDSAT TM, SPOT, or radar imagery using image analysis systems. GIS's are used for editing, correcting, modelling, and analysis in conjunction with map information. Information can also be generated in the GIS and used in image analysis processing for geocoding, stratification, masking, and image draping.

This paper describes examples of integration projects that have been performed in British Columbia, Alberta, Ontario, and the Pacific Northwest. The applications were developed for private and public sector clients in forestry, agriculture, and resource management. These projects provide examples of successful commercial applications involving integration of GIS with image analysis processes and data. They resulted in updated maps, enhanced image maps, and three-dimensional views of the data which could only be obtained by using both a GIS and image analysis.

Integrated processing has proven to be a commercially viable operation in forestry, agriculture, and resource management. Not only can it solve many of the problems in these areas, but in many cases, an image-based map will greatly enhance the decision making process. The use of this up-to-date information results in more informed planning and management decisions and also provides insights into actual resource usage.

While commercially viable, integrated processing is not being exploited. The purpose of this paper is to describe the learning process undertaken by Terrain Resources to develop the level of expertise required for commercial success.

LE TRAITEMENT INTÉGRÉ À L'AIDE DE SYSTÈMES D'ANALYSE D'IMAGES ET DE SYSTÈMES D'INFORMATION GÉOGRAPHIQUE : CONTEXTE COMMERCIAL

RÉSUMÉ

La technologie d'aujourd'hui rend possible le traitement intégré à l'aide de systèmes d'analyse d'images et de systèmes d'information géographique (SIG). Un nombre croissant de sociétés et d'organismes gouvernementaux au Canada et aux États-Unis mettent au point et commercialisent ce genre de traitement intégré. Les applications comprennent l'amélioration, la classification et le géocodage d'images LANDSAT TM, SPOT et radar à l'aide de systèmes d'analyse d'images, et la préparation, la correction, la modélisation et l'analyse à l'aide de SIG et de données cartographiques. En outre, il est possible de produire des données dans le SIG et de s'en servir pour le traitement des images à des fins de géocodage, de stratification, de masquage et de drapage.

Le rapport décrit des projets d'intégration qui ont été effectués en Colombie-Britannique, en Alberta, en Ontario et sur la Côte nord-ouest du Pacifique. Ces applications ont été développées en foresterie, en agriculture et en gestion des ressources, pour des clients des secteurs privé et public. Ce sont des exemples d'applications commerciales réussies de l'intégration des SIG et des systèmes et données d'analyse d'images. Ces projets ont eu pour résultat la préparation de cartes à jour, de cartes images améliorées et de vues tridimensionnelles de données que l'on n'aurait jamais obtenues sans l'utilisation à la fois de SIG et de l'analyse d'images.

Le traitement intégré est une opération rentable en foresterie, en agriculture et en gestion des ressources. Il permet de résoudre tous les problèmes qui se rencontrent dans ces domaines; en outre, dans bien des cas, la présence d'une carte fondée sur des images facilite le processus décisionnel. Cette information plus à jour permet de prendre des décisions de planification et de gestion plus éclairées et donne un aperçu de l'utilisation véritable des ressources.

INTRODUCTION

Integrated analysis involves the use of two or more systems to collect, analyze, and process the data. For spatial data this can involve the use of a data collection system, an Image Analysis System (IAS), a Geographic Information System (GIS), a Data Base Management System (DBMS), and a statistics package. Each system is used to perform a specific type of operation on the data during the overall process. If the objectives are analyzed carefully and the processing is designed with them in mind, the results can be significantly enhanced. The old adage "the whole is more than the sum of its parts" applies to this type of processing. In many cases a single system is used to process spatial data and the results do not meet the requirements of the end user.

Integrated analysis is particularly suited to image-based or image-derived products. However, there have not been many examples of this type of value-added product being done on a commercial basis for private or public sector clients. In addition to the work described in this paper, Terrain Resources and Timberline Forest Inventory Consultants have performed a baseline thematic mapping project at 1:20,000 scale for the Surveys and Mapping Branch of the B.C. Ministry of Crown Lands. There is a similar project underway for mapping a 1:250,000 scale on Vancouver Island by Reed Collins for the B.C. Ministry of Environment, Lands and Parks. An old growth mapping project was performed at 1:250,000 scale by the Ontario Remote Sensing Centre and the Ministry of Natural Resources. Another old growth and ground cover mapping project for the U.S. Forest Service Region 6 in the western U.S. was carried out by Pacific Meridian Resources Inc. A series of smaller projects by firms such as Interra Kenting, Geodat Information Services and Geomatics International provide further examples. Some of these projects are "proof of concept" studies or applications development projects, but in most cases, their objectives have a particular operational or planning requirement in mind.

PROCESS DESIGN

Once it has been decided that a problem lends itself to integrated analysis, i.e., some combination of GIS, image analysis, or database modelling, the next task is determining the kind of integration analysis that needs to be performed. Which integration methods need to be taken out of the tool box? The answer lies in looking at the flow of information during each step of the analysis. What data will be moved to what domain in what form? It is very important to pay attention to the "route" before analysis begins. Processing in the early stages will often have an impact on the choice of options two or three steps further along in the analysis. The choice of routes can also influence accuracy, as well as affect the time required to carry out transfers between domains.

This paper will concentrate on examples of integrated analysis which use GIS, IAS, and DBMS software to solve a variety of spatial data problems. All of the processing was performed on personal computers using a PAMAP Geographic Information System (GIS), a PCI Image Analysis System (IAS), and dBase as the Data Base Management System (DBMS).

There are three basic exchanges that can occur between the systems:

1) transfer of data,
2) exchange of parameters,
3) transfer of results.

The transfer of data is the most obvious process flow and, as it involves the largest amount of information, it is usually a one-way route. This could involve moving imagery from the IAS into the GIS or importing attributes into the GIS. A transfer of this type involves data which will be combined with other data to form a final data set. The exchange of parameters usually requires that both systems have data to work with in their own domains. These transfers can be two-way as they often have small amounts of information. An example of this type of exchange would be the definition of signatures for the IAS based on map information in the GIS. In this case the mean, standard deviation, and possibly the covariance and correlation matrices for each class would be transferred from the GIS to the IAS. An example of a transfer of results could be the movement of classified imagery from the IAS to the GIS or the calculated results of a model from a DBMS to the GIS. These types of data are completely defined and can be used as they are without additional analysis.

CASE STUDIES

Examples of integrated analysis carried out by Terrain Resources will be used to demonstrate the process. The flow of information varies in amount and direction, and some examples are more complex than others. There is a steep learning curve associated with most types of integration work, not just with sophisticated forms, as one might expect. Thus, these examples are presented in the order in which they were performed to demonstrate the development of the integration processing capabilities at Terrain Resources. Integrated analysis is seldom as simple as moving data from one domain to another and making a final product. There are four main factors to take into account when designing the integration process:

1) required results,
2) the type of analysis,
3) accuracy, and
4) the specific functionality within each system.

These are but a few of the considerations. The goal of this paper is to show, with case studies, some of the various integrated analysis that Terrain Resources has performed to provide data which are used in a commercial environment.

CROP RESIDUE MAPPING

Crop residue mapping, for operational "in-field" use, is a fairly simple form of integrated analysis. However, from a research perspective, this type of analysis could be taken much further. The present implementation for crop residue mapping is a generalization of the ground cover into broad classes. The ground cover is grouped into grassland (native or seeded), water, urban areas or low, medium, or high crop residue. All analysis and filtering is carried out in the IAS with the final image transferred into the GIS. In the GIS, the classified data are integrated with linear features such as roads, section lines, and rivers, and a final hardcopy is produced.

The objective is to produce a low-cost image map that will be used in the field. Crop residue maps can be used to show a farmer or rancher where they do not, or will not, have erosion problems. The idea is to focus attention on the high risk areas for immediate short term response.

As this is a simple linear process, the only exchange is the transfer of results from the IAS into the GIS. There are no data or parameter exchanges.

IRRIGATION MONITORING

The monitoring of water use in irrigation districts is a moderately complex form of integrated analysis. The basic legal cadastral data are collected and entered into the GIS to define the property boundaries and the known land use. The information that defines the irrigable areas are also entered in the GIS. These are areas which have a legal entitlement based on permanent or terminable water rights.

The second stage is to map the areas which each farmer irrigates during a given year. This is difficult to measure as it is an ever-changing area during a growing season. For this type of analysis the IAS is used with satellite imagery classified into different land-use categories.

This type of analysis gives managers a better insight into the water utilization in different parts of a large irrigation district. It also provides information on violators who irrigate more land than is legally permitted. More importantly, this type of analysis allows the managers of the irrigation district to assess water usage more accurately than with previously used techniques.

In the initial stages, the GIS is used to import ground control segments and other data to geometrically correct the imagery. The bulk of the work is performed in the IAS to classify the raw input imagery into a land-use map. The final stage of the analysis is the comparison of the data in the GIS to create a thematic map of water rights violations.

A fairly simple classification of an area into three classes: "cropped and irrigated", "cropped and not irrigated", and "other", is performed. Imagery is collected in the spring after the first irrigation cycle or application of water. The objective is to maximize the infrared differences between irrigated and non-irrigated areas. The difference in germination, initial growth, and increased biomass after irrigation can be distinguished from the same crop on adjacent dryland fields and from other dryland crops. Because of the patterns that develop in a field with wheel-move, and particularly, centre pivot irrigation systems, it is a very straightforward process to identify the irrigated areas. Thus, the selection of training samples for classification is simple and accurate. When a suitable set of classes has been produced, simple mode filtering and single pixel removal is done in the IAS before the classified image is exported to the GIS.

In the GIS, the classified image is converted into a polygonal cover and overlaid with the polygons which define the irrigable acres. Any discrepancies between the coverages are immediately detectable as two classes: "irrigable but not watered", and "not irrigable and watered". It is the latter combination which identifies the parcels and owners with water rights violations. The accuracy of identifying these areas depends on the match between acquiring the image and the stage of crop development. The type of irrigation practice can also have an effect on the accuracy. It is possible to detect violations as small as 5 to 10 acres in size. Bearing in mind that edge effects are common, irrigated acres can be mapped to ± 1 or 2 acres when the parcels are 60 to 80 acres or larger in size. The resultant water rights violation map can be used as a surveillance tool which will tell a manager very quickly where there are problems. These areas, once they have been identified, can be visited and surveyed for litigation purposes if it is necessary.

In this example, the only exchange is the transfer of data from the IAS into the GIS where it is combined with other data to produce finished results. Once again, this is a simple linear process, with no parameters or results exchanged.

SALINITY PROBABILITY MODELLING

Salinity probability modelling is an integrated strategy developed by Terrain Resources for the mapping and monitoring of soil salinity on agricultural lands. It is an example of a more complex analysis with a moderate amount of movement between domains. A number of steps are involved.

1) An image-to-map or image-to-image registration of an image is performed using ground control points to ensure sufficient correlation between the images and maps. The georegistered imagery is then classified with a "salinity driven" ground cover theme using a LANDSAT TM scene of the area.

2) The classified imagery is sent to the GIS as a surface level and converted into a polygonal cover in the GIS. The descriptive information from the classification is entered into a database and linked to the polygons.

3) Additional thematic information is entered into the GIS for coverages describing soils, ephemeral lakes, sloughs, Canada Land Inventory data, etc.

4) Slope, aspect, and elevation classes are derived from digital terrain modelling performed in the GIS. The terrain information is used as an additional variable in the model when appropriate.

5) The input data are defined as polygonal levels with a database containing the descriptive information. The descriptive attributes can be stored in the GIS, in the DBMS, or both systems.

6) The polygonal coverages are overlaid with each other to analyze the spatial relationships between different polygonal coverages and to identify the common or shared attributes.

7) The results from the spatial overlay of multiple polygonal layers are sent to the DBMS as input for the probability model. The model associates the value of an attribute from each of the overlaid levels to the likelihood of it contributing to soil salinity. A "reliability" weighting is also introduced into the calculation for each input attribute. This process is performed in the DBMS as the model had been developed in that system. The same type of process model can be run in the GIS eliminating a data transfer. In either case, the result is the calculation of the probability of an area being saline.

8) The model results are used to create a new thematic polygonal coverage in the GIS which is used for making maps and other products.

9) Ground truth entered into the GIS as a salinity, wetland inventory, or a Level II land classification, is used for accuracy assessment. An overlay of the ground truth, with results from the modelling, creates a thematic difference map that shows the variation between the coverages. If the analyst decides it is appropriate to do so, three bands of the LANDSAT TM scene can be transferred to the GIS from the IAS. Vector and database information is then displayed with the satellite imagery permitting on-screen interpretation and data entry.

In terms of data movement, there are several transfers in this process:

GIS to IAS if an image-to-image registration is used.
IAS to GIS if the imagery is already georeferenced.
GIS to DBMS for modelling.
DBMS to GIS for final analysis and presentation.

Initially the GIS was not used for thematic masking in the IAS to stratify the classification based on ancillary data. The GIS was also not used for quality control during the classification process. This kind of two-way movement was not in place at the time this work was performed and will be discussed in the next study.

BASELINE THEMATIC MAPPING

Baseline thematic mapping (BTM) is the extraction of ground cover information from imagery and the production of thematic maps. This is an example of a complex analysis involving multiple interactions between the GIS and the IAS. During the classification and filtering process involved in producing a thematic map from satellite imagery, there are several exchanges of information. The IAS performs the actual classification of the raw imagery into a thematic representation. The quality control and some of the definition for the classification is performed in the GIS. It is much easier to inspect and analyze the data in the GIS as it permits comparisons to reference data. Operations such as overlays of linear features, modifications to pixel values, thematic masking based on database attributes, are all performed in the GIS. This project involved six major stages:

1) input data processing,
2) image preparation,
3) ground truth,
4) image classification,
5) post processing,
6) accuracy assessment.

Following is the description of each stage in the integrated process.

INPUT DATA PROCESSING

1) Digital LANDSAT TM satellite imagery is imported into the IAS.

2) The digital version of the 1:250,000 map that encompasses the study region is translated into the GIS. This data is then merged into a smaller scale map base.

3) For terrain information, contours and spot heights from 1:50,000 NTS maps that cover the study area are digitized into the GIS. A digital elevation model (DEM) is built from the contours and spot heights.

4) A set of swamp or marsh polygons are also digitized into the GIS from the 1:50,000 NTS map.

5) The polygons and the DEM are used to generate a muskeg coverage for thematic masking in the classification process.

6) Available information on the study area, including soils, fire history, disease history, forest cover, land-use, habitat, etc., are collected and where possible, entered into the GIS.

IMAGE PREPARATION

1) Image georeferencing is performed with ground control points (GCP's) for an image-to-map tie-down. The GCP's linework from the 1:250,000 map base in the GIS are transferred to the image database in the IAS. The tie-down is performed with a cubic convolution, producing imagery with map coordinates. This permits comparison with other map information in the GIS.

2) Image enhancement using a linear contrast stretch, is performed on each band to bring out, or accentuate, spectral differences.

3) The geocoded enhanced TM bands 3, 4, and 5 are transferred to the GIS and displayed as a Red, Green, and Blue colour image. The composite image is combined with various types of linework in the digital map base, including contours and swamp/wetland polygons are loaded from 1:50,000 NTS maps. Highway (transportation), hydrology and NTS feature classes are also loaded from the 1:250,000 source file.

4) A perspective view of the 30 township region with planimetric linework draped over it is produced to examine the Digital Elevation Model generated using contours and spot heights from NTS maps. This process is performed in the GIS to verify the accuracy of the proposed image classes with reference to the ancillary map information.

GROUND TRUTH

1) To plan reconnaissance flights over the study region, a set of image and map base products are prepared using the GIS. These maps are used for analysis of the proposed ground cover classes.

2) A revised set of ground cover classes is developed with an interpretation of a hardcopy LANDSAT TM colour composite image at 1:100,000 scale. Additional analysis is performed on the actual digital image in the GIS with overlaid map data.

3) Forest cover and other ground cover descriptions, photographs, and videotape are collected to be used for preparing an interpretive key, and for selecting the training sites for the classifier during image analysis.

4) Additional information is collected during the reconnaissance flight over the study area. Ground truth is collected in the study area with a firsthand look at conditions on the ground in part of the study region. This provides an introduction to many of the forest cover classes and present land-use practices that are observed and documented during the reconnaissance flight.

CLASSIFICATION

1) In the IAS, the ground cover themes (i.e., classification results) are checked and readied for context filtering. Various parts of these themes are moved in and out of the GIS on a number of occasions for analysis and accuracy assessment. For example, a raster ground cover theme was moved to the GIS from the IAS for testing and inspection purposes.

2) The imagery is classified with a maximum likelihood classification using TM bands 3, 4, and 5. Classifications are performed with several other band combinations to assess the accuracy of the results.

3) The three-channel theme is 3 x 3 mode and context filtered to reduce the number of resultant polygons prior to exporting it to the GIS. The context filter was developed by the Surveys and Resource Mapping Branch of the B.C. Ministry of Environment, Lands and Parks.

4) Areas of cloud are identified in the IAS and removed in the GIS. Many corrections are possible in the GIS as it permits operator intervention and assignment of classes based on data layered onto the theme from other sources.

POST PROCESSING

1) The classification results described above are so-called "full-image" results. To optimize distinctions between some of the classes, the scenes are segmented using thematic masks. The elevation coverage, and the "swamp-march" coverage are used for this masking. The masking is performed in the GIS, as it is designed to operate on combinations of single and multiple variable surfaces.

2) The use of TM bands 3, 4, and 5 has been confirmed on two fronts. First, a review of the literature clearly suggested that 3, 4, and 5 is the most appropriate combination of bands for the kinds of ground cover classes that occur in the study area. Second, these bands were chosen by an algorithm in the IAS that evaluates the imagery to select optimal channels for analysis in terms of "class separability". With the ability to overlay map and ancillary data in the GIS, it has been noted that the set of bands giving the best visual enhancement is not necessarily the best set of bands for classifying an image into ground cover classes in the IAS.

ACCURACY ASSESSMENT

1) An overall mapping accuracy in the range of 85 to 90 percent has been achieved. This estimate is based on an error assessment in the GIS using Phase III forest cover maps and ground truth from the reconnaissance flight that was not used to train the classifier for image analysis.

2) The only exceptions are areas such as clear-cut classes, where some confusion between "status unknown" and "deciduous residual" can arise. Nearly all of this confusion is removable in the GIS with a class and polygon merge operation based on ancillary data.

This integration analysis involves transfers of data, parameters, and results between the IAS, GIS and DBMS. It is not a simple linear process, and the data or parameter transfers often go in both directions between the various systems. This is evident in the classification process during both the class definition and the accuracy assessment stages.

CONCLUSIONS

Probably the most important concept to be learned about commercial applications of integrated analysis is the definition of the level of accuracy. For commercial applications, the production of finished cartographic products is usually not the objective. Because of time and cost factors, as well as operational constraints, "useful" maps are the most appropriate goal. A useful map has the required level of accuracy for the required types of data. It is important to educate the users about the accuracy of these maps before designing the integration process. There will always be unclassified regions, mis-classified areas, inter- and intra-class problems, resolution accuracy, and edge effects in a classified image map. These errors can be reduced with more ground truth and temporal imagery, as well as additional time for processing. However, the most appropriate strategy is to design the processing to achieve the highest accuracy for the required classes, de-emphasizing accuracy levels of peripheral classes.

The form of spatial processing we have described as integrated analysis is still in its infancy. However, this situation is changing as more and more clients begin to appreciate the benefits of using the resulting data. At the same time, there are very few companies involved in, or entering into this field. This is mainly due to the steep learning curve that is part of acquiring the necessary expertise. Another barrier to companies operating in this field is the initial cost of hardware, software, and training. There also exists a very real shortage of properly qualified people to operate the systems and design the integrated data analysis procedures. This is not an entry level operation for GIS, IAS, or the other software involved in the analysis procedure. Finally, this type of service requires specialized marketing to sell it to prospective clients who are not aware of the advantages of integrated results. However, the benefits in terms of cost, time, and accuracy outweigh the initial trials and tribulations. In our experience, both the company and the clients have been very satisfied with the results. Hopefully the examples described in this paper have served to illustrate these advantages.

THE CHANGING CARTOGRAPHIC AND GEOINFORMATIC CURRICULA IN CZECHOSLOVAKIA

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Abstract

The CSFR belongs among countries with a traditionally good level of cartographic production, education and theory. Due to lack of information, limitation of international cooperation and particularly the technical retardation the social awareness of necessity of geoinformatics (GIS, remote sensing, GPS) behind advanced European and overseas countries. The author of this contribution deals with the trends of development of cartography and geoinformatics in the CSFR on the background of changes in the whole system of education in Czechoslovakia, the analysis of negative and positive aspects influencing the development of cartography and geoinformatics and the content of curricula before and after 1990, informing about them at universities and technical universities. He stresses the new possibilities of the development of those fields also with respect to international cooperation (Czechoslovak-Canada Cooperation in Remote Sensing, EAITS).

L'ÉVOLUTION DU PROGRAMME CARTOGRAPHIQUE ET GÉOINFORMATIQUE DE LA TCHÉCOSLOVAQUIE

RÉSUMÉ

La République fédérale tchèque et slovaque (RFTS) figure au nombre des pays qui sont toujours parvenus à offrir une bonne formation en cartographie et à maintenir un niveau élevé de recherche théorique et de production dans ce domaine. Toutefois, faute d'information et en raison du ralentissement de la coopération internationale et principalement du retard technologique, la société tchécoslovaque est aujourd'hui moins sensibilisée à la nécessité des travaux en géoinformatique (SIG, télédétection, SPG) que les habitants des pays évolués d'Europe et d'outre-mer. L'auteur de cet article examine les tendances cartographiques et géoinformatiques observées dans la RFTS en tenant compte des changements survenus dans tout le système d'éducation du pays. Il analyse en outre les aspects positifs et négatifs qui influent sur les progrès de ces deux disciplines, et il étudie les programmes offerts avant et après 1990 dans les universités et les établissements d'enseignement professionnel. L'auteur s'attarde particulièrement aux différentes options qui permettraient l'évolution de la cartographie et de la géoinformatique, dans le contexte de la coopération internationale (Accord Canada-Tchécoslovaquie de collaboration en télédétection, EAITS).

1. INTRODUCTION

Unlike geoinformatics (GIS, remote sensing, GPS), Czechoslovak cartography has a tradition of long standing. Names likes Šalason, Kuchař, etc. have been known to numbers of generations of map and atlas users, both specialists and the broad public.

Teaching cartography at universities has for years been linked up above all with teaching geography. Further, cartography is more and more becoming a part of education of surveyors and topographers organized by technical universities.

At present cartography is in intense interaction with very many branches of science, forming new parts of thematic mapping in contact with them and, as a whole, becomes a science of a comprehensive character of many points of view, oriented at the time/space representation and research of objects, phenomena and processes around us. In solving those problems cartography utilizes general scientific principles, methods and means of cognition, above all modelling and system-structural analysis, using broadly information, probability, statistical and other approaches. Most of the above characteristics would be out of reach without progress in geoinformatics.

These circumstances are also reflected in the development of cartography and/or geographical cartography in the countries of what is called eastern Europe. After World War II, and particularly in the last 30 years, thematic mapping has been developed, particularly in making maps from the sphere of physical geography, geology and other fields dealing with the natural components of the environment. Later on also mapping from economic and social geography and geodemography became more important and in recent years more accented themes of the environment. Especially in the latter case they were not allowed to be published or their content was strongly transformed, "in order not to shock the publisk" and cause panic, such as in the case of cancerous diseases and the dependance of their occurrence on the strongly polluted environment.

The development of Czechoslovak cartography after the war was strongly affected by Soviet cartography, particularly the Moscow school of Prof. Salistschev and his disciples. This operation was positive, particularly in the last years (Berlyant, Tikunov), especially with respect to geoiconics, mathematical-cartographic modelling, cartographical methods of research, etc. As negative can be denoted the fact that up to 1990 free

access to information about western cartography and geoinformatics was considerably limited, both for political, ideological and financial reasons (lack of money for literature in western currencies, travel and accommodation costs, etc.).

Geoinformatics (GISs) appear in the curricula of geographers only at the beginning of the 1980s in Brno, where also first summary book about GISs in the central and eastern Europe appeared (Konečný, Rais 1985).

2. CHANGES OF STUDY FORMS

Before characterizing the teaching of cartography and geoinformatics it is necessary to inform about fundamental changes in the university education in Czechoslovakia. Unlike the time before November, 1989, the individual universities and faculties have a much greater independence. This independence is also reflected in the concept of teaching the individual branches of science. Unlike the former forcibly unified concept of teaching, it is now more markedly dependent on personalities working at universities and on the overall background of the departments. In accordance with the act on universities kinds and possibilities of studies have been newly specified. I will show it on the example of my home university, Masaryk University and its Faculty of Science.

The Faculty provides bachelor studies in mathematical, physical, chemical, biological and geographical sciences and in the branches of study informatics (computer science) and environmental studies, master studies for specialists and teachers, post-gradual studies as well as life-long education of citizens.

The faculty awards the degrees of "Bachelor (Bc)" and "Master (Mgr.)" and the scientific degree of "Doctor (Dr.)" among others also in geography and cartography. Studies for specialists and teachers are organized in the following forms:

- full-time studies for school-leavers of secondary schools,
- extramural studies for school-leavers of secondary schools,
- extension studies for graduates of universities and bachelors.

For those who want to pass parts of study programmes within the life-long

education of citizens the faculty organizes extraordinary studies and special courses. One of the forms of extraordinary studies is a stay whose length is individual, as a rule 3 years.

Bachelor studies for specialists, in the full-time form lasting 3 years, is completed by passing the state examination. The graduates are awarded the degree of Bachelor (Bc.). Master studies for specialists in the full-time form takes, as a rule, five years, and is completed by passing the state examination, part of which is the presentation and discussion of the diploma thesis. The graduates are awarded the degree of Master (in Czech magistr, Mgr.). This two-step study grants the possibility of finishing the studies after 2.5 or 3 years and/or continue the studies also at another faculty or university, also abroad. Post-gradual studies take, as a rule, 3 years, being completed by presenting and discussing the dissertation thesis and a rigorous examination. The graduates are awarded the university and scientific degree of Doctor (Dr.).

For the sake of completeness I would like to add that the master studies for teacher concerns, as a rule, two branches, granting in either branch the following qualification alternatives: secondary school teacher, special teacher, or Mgr.

The content and extent of education is limited by the study curricula of the study branches, study orientation within study branches and/or in the interdisciplinary or interfaculty studies. The curricula proper includes subjects whose pasing in obligatory for the study branch. Further it includes subjects which form the technical orientation of the study, the "optional" subjects. The student can complete his or her curricula by subjects included in the study curricula of other study branches or faculties.

3. THE PRESENT STATE OF EDUCATION OF CARTOGRAPHERS AND GEOINFORMATICIANS AT CZECH, MORAVIAN AND SLOVAK UNIVERSITIES.

The teaching of cartography and geoinformatics is interconnected at all universities. The earliest to be included, in the early 1980s, was the lecture on GISs at the Department of Geography, Faculty of Science, Masaryk University Brno, but lectures on similar branches were also organized in Bratislava and at Technical University in Prague. The teaching the cartography and geoinformatics (in Canadian terminology geomatics) is organized at universities and technical universities. In the former case cartography is denoted as geographical, in the latter case as technical.

"Geographical" cartography", GISs and remote sensing are taught at universities within geography and cartography at the faculties of science of Masaryk University in Brno (Prof.Dr. Konečný, Dr.Drápela), Charles University in Prague (Prof. Dr. Mucha, Dr. Čapek), and Komenský (Comenius) University in Bratislava (Prof. Krcho, dr. Mičietová). Similar lectures, even if not to the full extent, are also held at Palacký University at Olomouc, West Bohemian University at Plzeň, and Ostrava University.

Cartography, but not GISs and remote sensing are part of education of teachers of geography at Pedagogical Faculties in Brno, Prešov and Nitra. At some universities cartography is taught as a part of further branches, even if at a limited extent to biologists, geologists, archeologists and students of environmental studies (Cartography of Environment).

"Technical cartography" is taught particularly at faculties of civil engineering of technical universities in Prague (Prof. Eng. Veverka) and in Brno (Prof. Maršík) and at the Technical University in Bratislava (Prof. Mitášová, Prof. Hájek). A recognized centre of teaching cartography is also the Military Academy in Brno (Prof. Srnka, Prof. Lauermann). The content of cartography teaching within the study of geography and cartography in the past years (on the example of Masaryk and Charles Universities) were the subjects Cartography and/or Geographical cartography, Thematic cartography, subjects concerning the processing of information, Utilization of computers in cartography, GISs, Remote sensing or Photointerpretation, Mathematical cartography, etc. The example quoted concerns the study of the specialization of geography and cartography. Less favourable is the situation in the education of geography teachers, where cartography is only taught in the first year.

At the faculties of civil engineering of the Czech Technical University in Prague and the Slovak Technical University in Bratislava the teaching included the following subjects: Topographical and thematical cartography, Computer and imaging technology, Mathematical cartography, Programming and computer graphics, Mapping, Records of immovable assets, Cartographical reproduction and polygraphy, Photointerpretation and remote sensing.

4. INNOVATION OF CURRICULA.

The concept of new curricula is affected - besides the above technical aspects - also by the calling of students for influencing them by their selfrealization, the possibilities of variant studies. Changes have also

taken place in the length of studies. At technical universities the formerly 4-year study of cartography was extended to 5 years. No doubt it was done due to the extension of the study by the studies of geoinformatics. At the universities the curricula were regrouped, on the one hand due to the above two-staged system of studies, on the other hand due to new study orientation , such as Geographical cartography and geoinformatics at Brno university.

At universities and technical universities one start from the above basis and the optional subjects. These the optional subjects penetrate the whole teaching of the Czech technical university (CTU)in Prague, whereas at universities they appear from the 3rd to 5th years, i.e. in the Master studies. At the CTU Prague, faculty of civil engineering, department of mapping and cartography, the student studies the above subjects plus the optional ones, which include: Programming in BASIC, Computer cartography, Cartographical methods of research, Selected chapters in mathematical cartography, Seminar in mathematical cartography, Polygraphical, Reprographical and special Micrographical seminars, Geography of Czechoslovakia, Cartographical application in remote sensing, Seminar in photogrammetry, Photogrammetry in building, Thematic mapping, Seminar on the use of computer technology in the State Cadaster of immovable assets, and Seminar on modern technique of mapping. At universities in Prague, Brno and Bratislava obligatory subjects include the above ones, which are completed by optional subjects within the Master studies. Thus, in Prague within the specialization Cartography and remote sensing they are: Cartographical representation, Cartometry, Cartographical bibliography, History of cartography, Regional maps of the world,Physical fundamentals of remote sensing, Drawing maps, Fundamental Mapping, Data acquisition in remote sensing, Experimental radiometry, Editing and compiling maps, Fundamentals of processing remote sensing data, Analog processing of remote sensing data, Cartographical toponomastics, GISs and remote sensing, Cartographical polygraphy and Atlas cartography.

At the Departmet of Geography, Faculty of Science, Masaryk University, Brno, the concept of the Master studies was determined on the basis of the new requirements of present day. The study orientation of Geographical cartography and geoinformatics takes into consideration both the development trends of cartography and geoinformatics and the expected problems and thus the increased interest in graduates, particularly in the socio-economic sphere and that of the environment. Further, the market economy is taken into consideration, with whose laws, requirements and all other aspects there is not any experience yet in CSFR. A certain role is also

played by the fact that a considerable part of the graduates will, unlike in the past, work in the state sector, but in the private one. And, last but not least, the orientation tries to include the aspect connected with the international cooperation with respect to the expected inclusion of the country among advanced European and overseas countries.

The Master studies link up with the obligatory basis by the following subjects (giving the extent of lectures and exercises and/or seminars in the winter and the summer terms): Computer cartography (2/3), Fundamentals of economy (2/1), Fundamentals of sociological research and regional sociology (2/1), Theory of regions and typology (2/0, 2/2), Geography of central Europe (2/1), Mathematical cartography (2/1), Atlas cartography (2/0, 0/2), History of cartography (2/1), Remote sensing in landscape investigation (0/2), Toponomastics (2/0), Cartographic making and editing maps (2/1, 2/2), Organization and control of cartographic production (2/0), GISs in territorial planning and urban studies (2/1, 2/2), Regional geography of the world (developed and developing countries) (2/2, 2/2), Regional planning (2/1, 0/2), Expert systems in geography and cartography (2/1), Automation in cartography (2/2), Cartographic polygraphy (2/2), Organization and control of publisher and editor activity (2/0), Global databases (2/0, 0/2), Socioeconomic development of selected regions (1/2), Special seminar (0/5), Diploma seminar (0/2), Excursion in a cartographic enterprise (2 weeks), Excursion about the CSFR (2 weeks).

A new trend at the universities is also the creation of organizational assumptions. Laboratories and departments of cartography, geoinformatics and remote sensing are set up. At the Department of Geography, Faculty of Science, Masaryk University, Brno such a laboratory is being established on the basis of the common Czechoslovak-Canadian project founded by the Canadian Task Force and coordinated by CCRS in Ottawa.

5. PRESENT SITUATION AND NEEDS AND PROSPECTS OF INTERNATIONAL COOPERATION.

In the CSFR information systems are not new. As early as in the early 1970s the first concepts of IS about territory were formed, technical assumptions appeared in the form of the device Digikart developed by the Czechoslovak People's Army. It was of solely Czechoslovak production and, besides the army, several specimens also served the civilian sector. During the 1970s and 1980s the negative aspects prevailed over the positive ones (Konečný, 1991). The former included little information about the development of the GISs and cartography in the world, few personal contacts, little domestic technology and embargo on technology from abroad, little

awareness of necessity and importance on geoinformatics. The positive aspects included the existence of a number of capable programmers who managed to partly eliminate the impossibility of purchasing top software in the West, enthusiasm of several individuals mostly from universities in Brno, Bratislava and CTU in Prague, the Geographical Institute of the Czechoslovak Academy of Sciences in Brno, cartographical and geodetical enterprises played a great role. Very important was also the support of international organizations, particularly the International Cartographic Association (ICA) (Dr. Morrison, Prof. Taylor) and International Geographical Union (IGU) (Prof. Muller, Prof. Brassel).

After the "velvet revolution" the situation changes, especially in the sphere of GIS, remote sensing and GPS (the latter have so far been known to several specialists). The ratio between the negative aspects is being balanced at a quicker rate. The main characteristics are: higher awareness, more information about new technologies, accessibility of literature is higher.Of extraordinary importance is also a new style of management and decision making in the Czechoslovak society,particularly in the political, economic, and land planning spheres, the solution of serious to critical problems of the environment. The responsible workers feel and observe the need of working with new methods, but most of them do not know the possibility of GIS and therefore they do not require and use them.

Among the negative aspects of the problem belong the vagueness about the centralization and decentralization in handling special type of spatial information, problems of the copyright and data standardization, the lack of financial means and the inaccessibility of top foreign literature.

The remove the above drawbacks and the final prevalence of positive aspects above the negative ones up-to-date technology(not out-of-date one) is essential, as well as know-how, experience with introducing GIS into administrative processes and activities, such as regional planning, decision making and management. It is essential to bridge the gap between advanced technologies and those existing at present in CSFR. Of great importance is international cooperation.

Closely after the revolution, at the end of 1989, representatives of a number of firms were coming to CSFR, in an overwhelming number of cases with a sincerely intended effort to help. Thus a number of institutions was equipped with the version ArcInfo PC by the firm ESRI, the IBM donated the 3090 IBM computer which is utilized from data processing to E-mail also by other universities, the firm Intergraph is becoming established in

the sphere of cartography, geodesy, etc. But not always did specialists from abroad come with accurate information about the level of knowledge in this country and about our most pressing needs. Sometimes we met incredible underestimation of the knowledge and abilituies of our specialists. This approach mostly originates from confusing the situation in the post-communist countries and thus also in the CSFR with the situation in the developing countries. Whereas in this country there is a level of education comparable with that of the world and a great number of specialists are able to overcome in a short the differences in knowledge and cross the imaginary precipice, in the developing countries the situation is quite different. On the other hand, in a number of developing countries it is possible to come across advanced technological equipment (even in the region of geomatics), which was missing in thre post-communist countries and is still missing.

One of the most interesting, well thought-out and sensitively recting to present situation projects I have met personally is the project developed by the Task Force and organized by the CCRS in Ottawa (Bill Bruce, Joseph Cihlar, etc.). The project consisted of the knowledge of the real situation in the CSFR, tipping the top specialists working in the area of education, forestry and environmental monitoring. These specialists were invited to Canda where, together with the domestic specialists, they set up the text of the project proper, and get the possibility of getting acquainted with the style of work, production and the commercial policy of foremost Canadian firms and universities. The project which is a part of the aid of Canada to CSFR does not only count with suplying the software, but also the hardware, which will form the essential and in the first stage the necessary assumptions for the applications of GIS, remote sensing and GPS under Czechoslovak conditions. I greatly appreciate particularly the fact that the project also counts with education. Why, what other way is there from the vicious circle of incomplete information, technical lagging behind and incorporation into international research and the solution of spatial problems but education?

6. CONCLUSION

In the CSFR progressive changes in teaching cartography and geoinformatics are under way. The acceleration of these changes occur on the background of a number of changes of Czechoslovak society and new conditions of education, technology, international cooperation and exchange of information.

In teaching cartography and geoinformatics there are changes in the curri-

cula in the sense of their modernization and introducing lectures, exercises and seminars increasing their knowledge and skills in utilizing GIS, remote sensing and GPS. These changes are aided by:

- increasing the awareness of the necessity of solution of new problems, tasks by new methods and especially means.The special and general public becomes acquainted with the advantages of using GIS and remote sensing;

- a gradual but constant increase of technology, althought at present it is concentrated on equipment by computers and basic peripheries (printers). So far very few institutions have been equiped with out-ofdate apparatus.There is an effort of educating students with abilities of adapting themselves to newly introduced technologies;

- a stronger stream of information from developed countries, the possibility of studying abroad and/or combination of studying in the CSFR and abroad, staff exchange, etc.

- transfer of experience and know-how;

- common international multidisciplinary projects (Czechoslovak-Canada Cooperationin Remotre Sensing, EAITS);

I beleive that the fulfilment of these assumptions, including further adaptation and new design of curricula in the sphere of cartography and geomatics will create in the CSFR another international center of education of specialists in the above fields.

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Dr. Konecny has specialized in geography and cartography. He is currently Associate Professor of Cartography at the Department of Geography, Faculty of Science, Masaryk University, Brno, Czechoslovakia.

He has authored approximately 50 papers on related research. He has also co-authored the first scientific publication in Eastern Europe (1985) as well two textbooks on GIS, Computer Cartography and Computer Methods in Geographic and Cartographic Research.

Dr. Konecny recently chaired two major international conferences: 1987 - Euro Carto VI and 1991 the Brno-GIS '91 Conference. He is editor of the proceedings of these conferences and has also recently organized a meeting of the ICA in Brno. He is regular member of the IGU Commission on GIS and vice-chairman of the ICA Commission on Map and Spatial Data Use. He was a member of the Steering and Organizing Committees of many international cartographical and GIS conferences.

Dr. Konecny has been a leader or member of research teams in landscape - oriented research with GIS, leader of graduate, postgraduate and doctoral theses programs in GIS and remote sensing.

He has participated in three Svalbard Expeditions to map anthropogenic influence on environment.

UN DICTIONNAIRE DES ENTITÉS GÉOGRAPHIQUES AU GOUVERNEMENT DU QUÉBEC

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RÉSUMÉ

Dans le cadre du Plan géomatique québécois, le ministère de l'Énergie et des Ressources a la responsabilité de réaliser le dictionnaire des entités géographiques contenues dans les bases de données du Gouvernement du Québec. Ce dictionnaire, dont la sortie est prévue au printemps 1992, sera:

- Un **répertoire encyclopédique** qui regroupera toutes les entités géographiques sur lesquels les divers organismes du Gouvernement du Québec recueillent des données;
- Un **outil d'interrogation** qui permettra de retrouver les entités préaentes dans chacune des bases de données gouvernementales, qu'elles soient déjà informatisées ou non;
- Un **outil de recherche** qui identifiera les producteurs de données concernant chaque entité géographique;
- Un **outil de normalisation** qui fournira une définition pour chacune des entités, chaque définition étant unique et univoque;
- un **outil de planification du plan géomatique** qui mettra en évidence les chevauchements de responsabilité des diverses unités administratives.

La réalisation de ce dictionnaire a demandé la tenue d'une vaste enquête qui a impliqué 185 unités administratives relevant de 51 organismes publics québécois.

La communication fera état des diverses étapes de réalisation et présentera en détail le contenu de ce dictionnaire.

A DICTIONARY OF LAND-RELATED ENTITIES FOR THE GOVERNMENT OF QUÉBEC

ABSTRACT

The mandate to create a dictionary of land-related entities for use in the Québec Governmental Geomatic Plan was attributed to the ministère de l'Énergie et des Ressources. This dictionary whose publication is set for spring 1992, is best described by the following:

- An **encyclopedia** regrouping the whole of land-related entities on which the different governmental bodies collect information;
- A **query tool** that will permit the retrieval of the different geographic entities contained in governmental data bases, whether they are already computerized or not;
- A **tool for research purposes** where data producers will be identified with regards to each geographic entity;
- A **tool for standardization purposes** where each geographic entity will be defined, each definition being unique and univocal;
- A **tool for planning within the Geomatic Plan** that will uncover the overlap of mandates between different administrative bodies.

The realization of the dictionary has commanded a major effort where 185 government units attached to 51 public administrative bodies were consulted.

The conference will give an overview of the different stages of the project and present a detailed account of the content of the dictionary.

1.0 Historique

En février 1989, le Comité directeur du Plan géomatique gouvernemental québécois confie au Secteur des terres du ministère de l'Énergie et des Ressources le mandat de réaliser un "dictionnaire des données à référence spatiale" qu'il définit sommairement comme un répertoire encyclopédique de l'ensemble des informations appelées à alimenter les futurs systèmes d'information géographique sur le territoire québécois.

Après une analyse préliminaire, l'équipe responsable de la réalisation de ce dictionnaire - le Groupe Inventaire-Dictionnaire (GID) - en arrive aux constats suivants:

- Toutes les unités de l'administration publique québécoise compilent quotidiennement des données dont l'étendue et la diversité sont souvent inconnues.

- Bon nombre de ces données concernent des entités géographiques qui pourraient être intégrées aux bases de données créées à la faveur du Plan géomatique québécois.

Pour mener à bien le mandat il fallait donc procéder à un inventaire et à une analyse systématique de ces données afin de produire un dictionnaire dont l'objectif principal est d'identifier et de définir avec précision ces entités géographiques. Ce dictionnaire des entités géographiques sera une étape préalable à la réalisation du Plan géomatique et à la production de dictionnaires de données à référence spatiale dont l'intérêt porte davantage sur les attributs de ces entités géographiques.

2.0 Étapes de réalisation

La réalisation du dictionnaire des entités géographiques comprend les quatre étapes suivantes:

- Réalisation d'un inventaire impliquant toutes les unités administratives susceptibles de compiler des données portant sur des entités géographiques;

  Note: Cette étape a pris fin en janvier 1991 par la production d'un document de 1 400 pages renfermant toute l'information recueillie.

- Production, impression et diffusion, au printemps 1992 d'une version préliminaire du dictionnaire;

  Note: C'est le document que nous décrirons dans les pages qui suivent.

- Évaluation d'un extrait du dictionnaire par une équipe de référence devant en analyser et en critiquer le contenu et la conception avant d'amorcer la dernière étape de réalisation;

- Production d'une version finale imprimée et aussi d'une version interactive devant être disponibles à la fin de 1992 ou au début de 1993.

La pérennité et la mise à jour de ces dernières versions dépendront des orientations futures prises par le Comité directeur du Plan géomatique québécois.

3.0 Clientèle

Le dictionnaire des entités géographiques s'adresse aux responsables de la mise en place du Plan géomatique dans les ministères et autres organismes du Gouvernement du Québec.

Il pourra également être utile aux producteurs et aux utilisateurs de données à référence spatiale qui oeuvrent au sein d'organismes publics et para-publics (municipalités locales et régionales, maisons d'enseignement, etc.) ou de certaines entreprises privées opérant dans des secteurs d'activités connexes au secteur public (Bell, Gaz Métropolitain, etc.).

Accessoirement, il pourrait aussi intéresser d'autres gouvernements, d'autres entreprises privées ou même le grand public (étudiants, etc.).

Le dictionnaire devrait donc rejoindre une grande variété de clientèles et, nous l'espérons, sera en mesure de répondre adéquatement aux préoccupations des producteurs et des utilisateurs de données à référence spatiale, qu'ils opèrent à l'intérieur ou à l'extérieur de l'administration publique québécoise.

4.0 Principales caractéristiques

Pour répondre aux besoins des clientèles identifiées, le dictionnaire doit être un outil universel permettant un premier contact avec les entités géographiques. Il a donc été conçu à l'image d'un **centre de documentation** et comme tel, présente chacune des caractéristiques suivantes:

- C'est un **répertoire encyclopédique** qui regroupe l'ensemble des entités géographiques sur lesquelles les diverses unités administratives du Gouvernement du Québec compilent des informations. Il transcende les structures administratives pour donner une vision globale des entités géographiques étudiées dans l'administration publique;

- C'est un **outil d'interrogation** qui permet à tout utilisateur de découvrir toutes les entités géographiques mais aussi les domaines d'emploi dans lesquels ces entités sont utilisées par l'administration publique québécoise. Cet aspect est particulièrement important et nous y reviendrons plus loin dans ce document;

- Déjà il constitue un **outil de recherche** puisqu'il identifie les unités administratives responsables des données associées à chaque entité géographique;

- C'est un **outil de normalisation** puisqu'il définit avec précision chacune des entités géographiques relevées. Chaque définition est unique et univoque;

- Enfin il sera au cours des prochaines années un **outil de planification du Plan géomatique** puisqu'il met en évidence, pour chaque entité géographique, les chevauchements de responsabilité des diverses unités administratives.

5.0 Contenu

Nous aimerions apporter quelques précisions concernant le contenu du dictionnaire, en soulignant au passage certaines données théoriques ayant servi à sa conception.

5.1 Les entités géographiques

Les notions véhiculées par le dictionnaire, sont exclusivement celles se rapportant aux **entités géographiques** présentes dans une ou plusieurs bases de données (informatisées ou non) du gouvernement du Québec.

Sont considérées comme entités géographiques, toutes **notions** dont les manifestations sont repérables physiquement ou légalement au sol et pouvant donc être représentées schématiquement sur une carte au moyen d'un point, d'une ligne ou d'un polygone.

La première version du dictionnaire contient plus de 1500 entités géographiques fournies par les responsables de l'inventaire dans les diverses unités administratives. L'exhaustivité et la qualité de son contenu dépendent largement de cette collaboration.

5.2 Les unités terminologiques

Pour identifier chaque entité géographique, nous avons retenu l'unité terminologique qui nous semblait la plus significative. Dans la plupart des cas, il s'agit des termes utilisés couramment par les unités administratives concernées. Aucun spécialiste de la langue n'ayant participé à l'opération, nous ne pouvons prétendre que celle-ci soit sans faille.

Pour compléter l'information concernant la désignation des entités géographiques, nous avons retenu tous les signifiants soulevés lors de l'inventaire. Ils situent les unités terminologiques retenues par rapport à d'autres termes en usage. Leur inscription en index avec renvoi approprié facilitera l'identification et la recherche des entités géographiques.(Voir figure 2)

5.3 Les définitions

La plupart des définitions ont été fournies par les responsables des bases de données ayant participé à l'inventaire. Lorsque plus d'une définition pour une même entité était proposée, la définition choisie pour ce dictionnaire est celle qui nous semblait la plus juste ou la plus complète. Dans d'autres cas, elle résulte plutôt de l'amalgame des informations contenues dans l'ensemble des définitions fournies par les répondants. Enfin dans quelques cas, les définitions proviennent de publications gouvernementales ou de publications scientifiques. Les responsables des bases de données concernées ont été invités à valider ces définitions.

A ce stade-ci , aucun spécialiste de la langue n'a été impliqué dans la réalisation de la version préliminaire, éventuellement ces experts seront appelés à donner leurs avis. Nous considérons cependant que les définitions sont suffisamment complètes, précises et exactes pour permettre aux utilisateurs de bien saisir la teneur réelle des entités géographiques.

5.4 Les domaines d'emploi et les relations inter-entités

Lorsque l'on définit une notion, en identifiant ses caractères, on se rend rapidement compte qu'une grande partie de sa spécificité lui vient des rapports qu'elle entretient avec d'autres notions qui lui sont apparentées.

Toutes les notions (y compris les entités géographiques) s'inscrivent en effet à l'intérieur d'un ou de plusieurs systèmes, plus ou moins vastes, où elles entretiennent des relations avec une ou plusieurs autres notions. En linguistique, ces systèmes fonctionnels sont appelés systèmes de notions ou champs notionnel. Nous les avons nommés plus simplement **domaines d'emploi**.

La classification des entités géographiques à l'intérieur des domaines d'emploi est à notre avis, une part essentielle de l'information véhiculée par ce dictionnaire. Par exemple, pour comprendre ce qu'est l'entité géographique "municipalité régionale de comté" ne doit-on pas savoir qu'elles est constituée de "municipalités". A leur tour, les MRC ont été regroupées pour former les nouvelles régions administratives du Québec; toutes ces relations relevant du domaine complexe des divisions administratives.

On trouvera dans les pages suivantes une description succincte de ce concept de système de notions. La figure 1 illustre un des nombreux domaines d'emploi présents dans le dictionnaire

5.4.1 Les relations inter-entités

Notre étude des relations inter-entités nous a permis d'identifier deux sortes de relations pouvant lier des entités géographiques. Ce sont les relations séquentielles et les relations hiérarchiques.

Les relations séquentielles

Les relations séquentielles sont des relations inter-entités où on retrouve un lien de dépendance entre deux entités. Elles se présentent sous deux types:

- Les relations où la dépendance est de type causal.

  Ex: Une "aire contaminée" par un polluant *(entité affectée)* entretient un lien de dépendance de type causal envers l'"usine" qui émet ce polluant *(entité causale)*

- Les relations où la dépendance résulte d'une simple contiguïté spatiale ou temporelle.

  Ex: Le lien unissant une "plantation forestière" *(entité subséquente)* à la "pépinière" qui a produit les plants *(entité préalable)* ou une "aire de protection" *(entité subséquente)* et le "monument historique classé" qu'il protège *(entité préalable)*.

Les relations hiérarchiques

Les relations hiérarchiques sont des relations inter-entités qui résultent de la division d'une entité super-ordonnée en une ou plusieurs entités de niveau inférieur ou subordonnées. Les relations hiérarchiques peuvent être de type **"générique - spécifique"** ou de type **"intégrant - partiel"**.

Relations hiérarchiques de type "générique - spécifique"

Relation hiérarchique dans laquelle chaque entité subordonnée ou spécifique contient l'ensemble des caractères de l'entité super-ordonnée ou générique.

Ex.: Tous les caractères de l'entité géographique "municipalité" *(entité générique)* sont contenus dans les entités géographiques "municipalité de village" ou "municipalité de paroisse" *(entités spécifiques)*.

Relations hiérarchiques de type "intégrant - partitif"

Relation hiérarchique dont l'entité super-ordonnée ou intégrante est le résultat de la somme des diverses entités qui lui sont subordonnées. L'entité intégrante est donc une entité géographique qui est considérée comme un tout, alors que l'entité partitive est une entité géographique considérée comme une partie d'un tout ou d'une entité géographique intégrante.

Ex: Une "communauté urbaine" est une entité intégrante par rapport aux diverses "municipalités" qui la composent. Ces dernières sont les entités partitives d'une communauté urbaine.

Dans la version préliminaire du dictionnaire, la description de chaque entité géographique précise le ou parfois les domaines d'emploi auxquels elle appartient, puis les relations inter-entités qui en découlent. Parallèlement toutes les entités géographiques appartenant au même domaine d'emploi sont regroupées dans un index classé selon deux ordres: alphabétique et systématique. L'index devient ainsi un instrument fort utile pour la recherche d'entités relevant d'une même problématique. (Voir figure 2)

6.0 La version finale

La version finale du dictionnaire des données sera interactive. Les divers modes d'accès nécessiteront le développement d'un logiciel qui, nous l'espérons, devrait contenir les fonctions suivantes:

- La consultation directe par les usagers à partir d'un micro-ordinateur;
- L'étude des domaines d'emploi et le passage rapide d'une entité géographique à une autre entité appartenant au même domaine d'emploi.
- La mise à jour continue ou périodique du contenu par les responsables des bases de données;
- L'impression d'une version originale et des mises à jour subséquentes.

Figure 1

Organisme: Ministère de l'Énergie et des Ressources (Secteur des terres)
Domaine d'emploi: Affectation des terres publiques

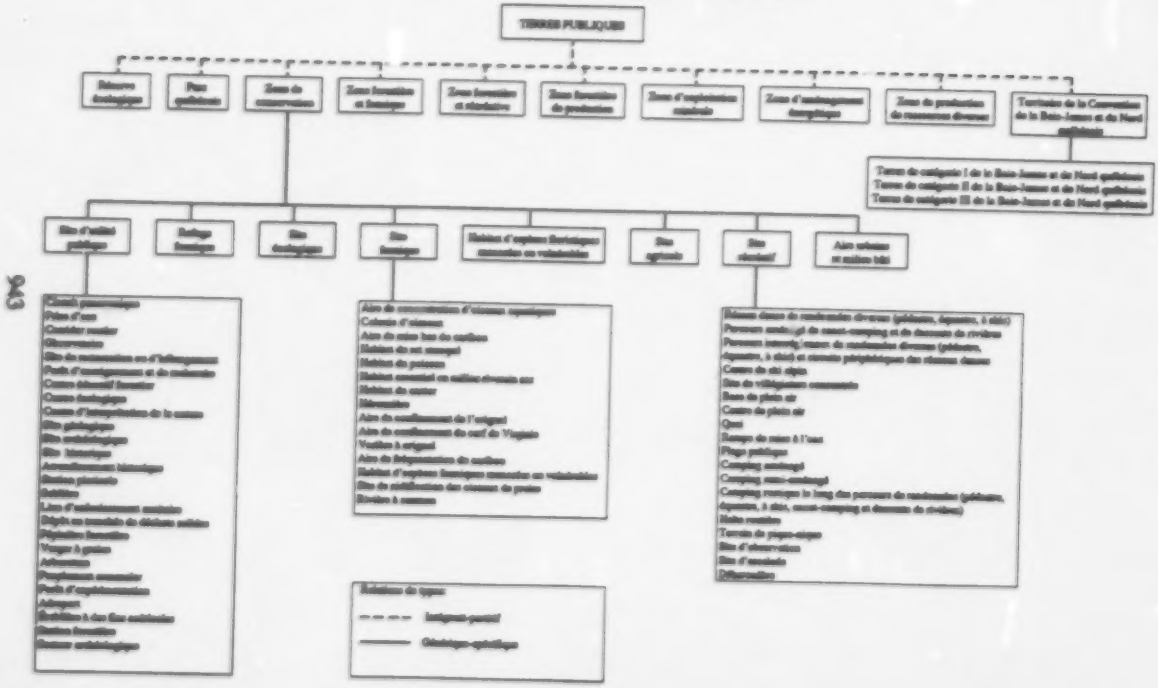

Figure 2

Extrait du corpus du dictionnaire et exemples de termes indexés

USING A GIS TO STUDY THE RELATIONSHIP BETWEEN SIMULATED ENVIRONMENTAL VARIABLES AND A VEGETATION INDEX

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ABSTRACT

The relationship over the Canadian landmass between global area coverage normalized difference vegetation indices (NDVI), evapotranspiration and percent soil water available is studied. The NOAA global area coverage 15-day composites are introduced into a geographical information system (GIS) in raster format and statistics of the NDVI are computed in an area surrounding the location of surface weather observation stations. Meteorological data in conjunction with vegetation and soil characterization data sets are integrated in vector format into the GIS. Data is extracted in the GIS environment and is used to simulate (with a multilayer soil water model) potential and actual evapotranspiration and percent soil water available. The main biomes considered are: farmland, rangeland, coniferous forests and deciduous forests. Six years (1982 to 1987) of data are analyzed.

Correlations between NDVI and potential evapotranspiration for

vegetation classes suffering from water stress are higher than for NDVI versus actual evapotranspiration suggesting that NDVI in northern latitudes is not a good indicator of water stress. However, generally, if a vegetation class is under considerable water stress then senescence occurs earlier.

Multiple linear regressions where actual evapotranspiration is the dependent variable and NDVI (of the following 15 day period) and potential evapotranspiration are the independent variables at best explain 66% of the variance (year 1982) and as low as 53% of the variance (year 1984). The explained variance is higher when the predicted variable is averaged over a class. It is also found that NDVI lags simulated evapotranspiration by about 15 days.

UTILISATION D'UN SIG POUR ETUDIER LA RELATION ENTRE DES VARIABLES ENVIRONNEMENTALES SIMULEES ET UN INDICE DE VEGETATION

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La relation sur le sol Canadien entre les indices différentiels normalisés de végétation (IDNV) provenant des satellites NOAA (les images ont une résolution de quatre kilomètres), l'évapotranspiration et le contenu en eau disponible dans le sol est étudiée. Les images NOAA composées sur une période de 15 jours sont introduites dans un système d'information géographique (SIG) en format matriciel. Les statistiques des IDNV sont calculées pour une surface entourant l'emplacement de stations météorologiques. Les données météorologiques ainsi que les données caractérisant les sols et le type de végétation sont entrées dans le SIG en format vectoriel. Des données extraites à l'intérieur du SIG sont utilisées pour simuler l'évapotranspiration potentielle et réelle et le contenu en eau disponible du sol. Les principaux types

de végétations considérés sont les suivants: agriculture, pâturages, forêts de conifères et forêts de feuillus. Six années de données satellitaires (1982 a 1987) sont analysées.

Les corrélations entre les IDNV et l'évapotranspiration potentielle pour des classes de végétation souffrant de contraintes hydriques sont plus élevées que pour les IDNV en fonction de l'évapotranspiration réelle. Ceci suggère que l'IDNV pour les latitudes moyennes n'est pas un bon indicateur de défaillance hydrique. Cependant, de facon générale, la sénescence d'une classe de végétation qui souffre de défaillance hydrique se produit plutôt.

Des régressions linéaires multiples où l'évapotranspiration réelle est la variable dépendente et l'IDNV (de la quinzaine suivante) ainsi que l'évapotranpiration potentielle sont les variables indépendentes expliquent au mieux 66% de la variance (pour l'année 1982) et au pire 53% de la variance (pour l'année 1984). La variance expliquée est plus élevée lorsque les variables sont moyennées par classe. Il a aussi été déterminé que l'IDNV suit l'évapotranspiration d'approximativement 15 jours.

A GLOBAL CHANGE ENCYCLOPEDIA

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Abstract

An interactive Global Change Encyclopedia (GCE), portraying the contribution that remote sensing from space can make to the monitoring of global environmental change on earth, will be produced for the International Space Year(ISY) in 1992.

Co-sponsored by the Canadian Space Agency and the Canada Centre for Remote Sensing (CCRS), and implemented under the direction of CCRS, the objective of the GCE project is to demonstrate to a large number of people around the world, through hands-on experience, that satellite data are of vital importance in monitoring the global environment. The project is also intended to illustrate the profound changes occurring in many parts of the world.

The data in the Encyclopedia will provide global coverage for more than fifty parameters from various remote sensing satellites and from ancillary map documents. Other related data, usually with greater spatial resolution, will cover continental and regional areas to illustrate more localized phenomena which are nevertheless linked to global environmental change (for example, El Niño, deforestation and desertification).

The data will be available on diskettes and CD-ROM optical disks. Initially 2 CD-ROMs will contain the global and regional data sets, however, given the volume of data available and being generated annually, there is certainly the possibility of future GCE data CD-ROMs. The Encyclopedia will operate on PC compatible microcomputer platforms in general use around the world. The first release for distribution of the GCE is planned for November 1992. The purchase cost of the GCE will be low in order to maximize its use worldwide. Initially, the GCE will be produced in both English and French versions.

UNE ENCYCLOPÉDIE DES CHANGEMENTS PLANÉTAIRES

Résumé

La réalisation d'une l'Encyclopédie numérique portant sur le thème de l'apport de la télédétection spatiale au suivi des changements environnementaux à l'échelle du globe est prévu pour 1992, l'année internationale de l'espace.

Le projet est co-parrainé par l'Agence spatiale canadienne et le Centre canadien de télédétection (CCT) et sa réalisation est dirigée par le CCT. Le but du programme est de démontrer à un grand nombre de gens dans le monde entier, au moyen d'expériences pratiques, que les données obtenues par satellite présentent une importance cruciale en matière de surveillance de l'environnement de la planète. Le projet vise également à mettre en lumière les changements importants qui s'opèrent dans plusieurs régions du monde.

Les données de l'Encyclopédie auront une converture mondiale pour plus d'une cinquantaine de paramètres provenant de divers satellites de télédétection ainsi que de documents cartographiques auxiliaires. D'autres données similaires mais à plus haute résolution spatiale, couvriront également des étendues continentales et régionales afin d'illustrer des phénomènes plus localisés, mais toujours reliés aux changements mondiaux (El-Mino, déforestation et désertification,...). Les données seront disponibles sous forme de micro-disques et sous forme de disques optiques de type CD-ROM. On prévoit que toutes les données de l'Encyclopédie seront contenues sur 2 disques optiques. Cependant, il est fort à prévoir il y aura des disques additionnels qui seront produits dans le futur étant donné le volume et la continuité d'acquisition de ce type de données. L'Encyclopédie sera fonctionnelle à partir d'une plate-forme micro-informatique de type PC compatible largement diffusée à travers le monde. La distribution initiale de l'Encyclopédie est prévue pour novembre 1992. Les coûts d'acquisition de l'Encyclopédie sont prévus les plus bas possibles afin d'en maximiser l'utilisation à travers le monde. Initialement, l'Encyclopédie sera produite en langues française et anglaise.

1. INTRODUCTION

The year 1992 has been designated as International Space Year (ISY). Over 25 national space agencies have joined in the Space Agency Forum for International Space Year (SAFISY) and have agreed on "Mission to Planet Earth" as the theme for this international year (Meyerson, 1988). The Forum and its panels of experts have planned for a worldwide program of activities that will highlight the importance of space observations and their enormous contribution to humanity.

The Global Change Encyclopedia project (GCE) has been accepted as the key project of the Global Change Outreach program. Co-sponsored by the Canadian Space Agency and the Canada Centre for Remote Sensing (CCRS), and implemented under the direction of CCRS, the objective is to demonstrate to a large number of people around the world, through hands-on experience, that satellite data are of vital importance in monitoring the global environment. The project is also intended to illustrate the profound changes occurring in many parts of the world.

The underlying principle is to assemble and structure large sets of digital remote sensing data and relevant ancillary digital data (maps, demographic information, etc.), and to make them available in readily accessible digital form on CD-ROMs or diskettes (Cihlar et al., 1991). Software accompanying the data will enable users to display and manipulate the information in the Encyclopedia on a standard PC microcomputer.

The target audience for this project includes high school and university students, young scientists and members of the general public interested in global environmental change. This worldwide audience will be multilingual, so the Encyclopedia will be adaptable to many languages. Initially the data sets, software and accompanying documentation will be offered in English and French versions.

2. OVERVIEW OF THE ENCYCLOPEDIA

The data contained in the Encyclopedia (more than two gigabytes) will consist of information from a wide variety of sources, in various formats, organized as follows:

- Images: which are global and regional continuous-tone images of geo-scientific parameters (such as surface reflectance, vegetation index, sea-ice concentration, sea-surface temperature, etc.) and geo-scientific maps derived from imagery in geo-referenced raster format.

- Maps: which are global and regional maps of coastlines, land cover, vegetation, climate, etc. in raster and/or vector format.

- Socio-economic maps: which are socio-economic and environmental statistics in tabular and graphic format by country.

- Illustrative photographs: which are photographs illustrating local flora, fauna and landscapes.

- Supporting text: which will provide explanations and references about the individual data sets.

The Encyclopedia will operate on an IBM PC-AT, or compatible, with a VGA graphics adapter, hard disk (40 Mb minimum), mouse (optional but highly recommended), CD-ROM reader and colour or B&W printer (optional). This hardware selection was based on its widespread availability throughout the world and its good graphics display capabilities.

The Encyclopedia will be offered in two different product forms: a CD-ROM version and a sub-set of this as a diskette version. The diskette version is intended for those who are interested in these data but do not have the time or inclination to examine or analyze the full CD version, or for users without access to a CD-ROM reader.

The CD-ROM and diskette sub-set will each include real data and the software needed to access, display and analyze them. Global data sets will be stored in raster, vector or alphanumeric form and geo-referenced by latitude and longitude. The regional data will be geo-referenced in various projections as provided by the contributors.

The overlay of vector linework on raster imagery and maps will be possible on the display screen, and the system will be able to capture, store and display annotation. The user will be able to browse imagery slides on the CD (using on screen hypermedia tools) and download selected portions of the data to a hard disk using the access software. The analysis software for processing the data will offer a limited set of raster GIS functions which can be used for manipulating and analyzing the downloaded data.

The software will function at different levels of complexity and flexibility, depending on the knowledge and experience of the user. The intention is that this package will provide a sampling of basic raster GIS and image-analysis functions, not a complete set of tools, to analyze and appreciate the value of the data. Users wishing to perform more complex analyses can do so by exporting the data to more complete GIS or image analysis systems.

3. THE DATA OF THE ENCYCLOPEDIA

The GCE data have been provided by the various space agencies participating in SAFISY (although primarily by NASA and by NOAA), and by more than fifty other scientific organizations around the world.

As mentioned above, various kinds of data will be incorporated in the GCE. The Table 1 (for global coverage) and Table 2 (for regional coverage) list the content of the data which are considered for inclusion in the Encyclopedia. There are more than 50 geo-scientific, biological, ecological, physical and chemical parameters related to the global environment, in addition to 240 socio-economic variables defined on a per country basis. Most of the global satellite parameters correspond to monthly average observations made from space during the 1980's.

In addition, the GCE has been designed to access vector data imported from another product identified as the Digital Chart of the World (Hum, 1991). These data will be available in mid-1992, and having a worldwide coverage, will complement the raster GCE data effectively. They have been obtained from the digitization of Operational Nautical Charts (ONC) at a scale of 1:1 000 000.

4. USING THE ENCYCLOPEDIA

The Encyclopedia software will facilitate innovative exploration and use of the global nature of the overall data set. In particular, the user interface will be of a very high level, with a stimulating, user-friendly environment, optimized to encourage and simplify

manipulation of large amounts of data. Moreover, the interface will be tailored to the global change context, with emphasis, for example, on the temporal nature of phenomena.

The Encyclopedia will be accessible at four main user options:

"Script" mode: The script mode will allow guided tours of slides (using hypermedia tools) and guided exercises with real data for various themes of the global change subject covered by the GCE. Topics to be addressed by these scripts (or stories) will include the Biosphere (which include Forestry, Agriculture,...), the Atmosphere (Ozone,...), the Hydrosphere (Oceans, Deltas,...), The Cryosphere (Glaciers, Sea Ice, Snow,...), The Lithosphere (Geodynamics) and the "Civilization" (Demography, Philosophy of Sciences, Health,...).

The practical exercises are a natural extension of the guided tours. Each exercise will encourage users to experiment with the input parameters and compare results. In this way, users will have a better understanding of the parameters which affect environmental processes and phenomena.

The user will also be able to develop their own scripts for the preparation of educational activities adapted to a given teaching program for example. This characteristic is considered to be a very important factor in stimulating use of the Encyclopedia in a school environment.

Explore mode: In the Explore mode the user can explore any specific group of images, as represented by slides, selected by themes (e.g. atmosphere or cryosphere) or by regions (global or regional). This will allow the user to appreciate the content of the data base before downloading real data from the CD to the hard disk.

Analyze mode: At this level, users will have access to the all analysis functions of the GCE (see Table 3 for detailed list). Actual analysis of the data can also be delayed in a batch queue for off-line processing (over night, for example, if lenghtly calculations are required).

Edit mode: This is the mode the user will choose to prepare his/her results for presentation on a map document. Output prints of their results on colour maps will be possible at this stage.

It is expected these four options will facilitate various conditions of use of the GCE for different user groups ranging from novices to experienced users. This will also simplify the exploration and analysis of this huge data base in distinct steps with an optimum level of control by the user at each level.

5. CONCLUSION

The production in 1992 of a digital and interactive Global Change Encyclopedia will be an important event in the activities marking the International Space Year. It is intended to increase public awareness of the contribution of space technology, remote sensing and geomatics to the monitoring and understanding of global environmental change. The Encyclopedia has been designed for ease of access by as many users as possible worldwide.

The 1990s will undoubtedly be a very important decade for establishing diagnosis and action strategies for our growing environmental problems. It is our hope that this Encyclopedia will contribute to greater understanding and encourage the research and international co-operation necessary for the sustainable development of our resources and of our communities.

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This information is subject to change

GLOBAL DATA SET INFORMATION — 29 JANUARY 1992 — TABLE-1A

#	TITLE	THEME	SOURCE	DATE	RESOLUTION
4	ISSCP CLOUD DISTRIBUTION	ATMOSPHERE	NOAA/TIROS-N	JUL 83 - DEC 86	2.5 - MIN
5	SAGE II AEROSOL CONCENTRATION	ATMOSPHERE	ERBS SAGE II	24 OCT 84-30 NOV 86	1 DEGREE
7	SSM/I ATMOSPHERIC LIQUID WATER	ATMOSPHERE	DMS SSM/I	JUL 87 - DEC 88	30 - MIN
10	CLIMATE ANOMALIES	ATMOSPHERE	METEO STAT.	1985 + ?	1 DEGREE ?
11	OUTGOING LONGWAVE RADIATION	ATMOSPHERE	ERB Nimbus 7	NOV 78 - OCT 86	4 DEGREE
12	AEROSOL (OPT.THICK)	ATMOSPHERE	NOAA AVHRR	2 YEARS	1 DEGREE
20	OCEAN SURFACE WIND SPEED	ATMOSPHERE	DMS SSM/I	JUL 87 - DEC 88	30 - MIN
21	SEA SURFACE TEMP.	HYDROSPHERE	NOAA AVHRR	OCT 86 - JUN 89	10 - MIN
28A	OZONE CONCENTRATION	ATMOSPHERE	TOMS	NOV 78 - DEC 90	30 - MIN
32	NOAA MONTHLY GVI	BIOSPHERE	AVHRR 1,2	APR 85 - DEC 88	10 - MIN
33	MATTHEWS WETLANDS	BIOSPHERE	MAPS	1987	1 DEGREE
34	OLSON WORLD ECOSYSTEMS	BIOSPHERE	MAPS	1970 - 1989	10 - MIN
35	MATTHEWS VEGETATION	BIOSPHERE	MAPS	1970 - 1989	1 DEGREE
36	SEA ICE CONCENTRATION	CRYOSPHERE	DSMP SSM/I	JUL 87 - DEC 88	10 - MIN
41	MATTHEWS CULTIV.INTENSITY	BIOSPHERE	MAPS	1970 - 1989	1 DEGREE
42	MATT. INTEGRATED ALBEDO	BIOSPHERE	MAPS	1970 - 1989	1 DEGREE
43	MSU TROPOSPHERE TEMPERATURE	ATMOSPHERE	NIMBUS/HIRS-MSU	1979 - 1988+	1 DEGREE
46A	FNOC TERR. ELEV.	GEOSPHERE	MAPS	1986	10 - MIN
46B	FNOC %URBAN COVER	CIVILIZATION	MAPS	1986	10 - MIN
46C	FNOC %WATER COVER	HYDROSPHERE	MAPS	1986	10 - MIN
47	MICRO WORLD DATA BANK II (MWDB II)	GEOSPHERE	MAPS	1986	
48	INTEGRATED ELEVATION AND BATHYMETRY	GEOSPHERE	MAPS	1985	5 - MIN
49	FAO/UNESCO SOIL MAP OF THE WORLD	GEOSPHERE	MAPS	1974	2.5 - MIN
63	OCEAN COLOUR PHYTOPLANKTON CONC.	BIOSPHERE	CZCS	NOV 78 - JUN 86	10 - MIN
78	EXPERIMENTAL MONTHLY GLOBAL NDVI PROD.	BIOSPHERE	AVHRR1,2	09 APR 85 - 30 DEC 90	10 - MIN
79	SMMR NORTHERN HEMISPHERE SNOW COVER	CRYOSPHERE	SMMR NIMBUS-7	NOV 78 - AUG 87	30 - MIN
80	MICROWAVE NDVI	BIOSPHERE	SMMR	1979 ?	30 - MIN
81	HOLDRIDGE LIFE ZONE	BIOSPHERE	VARIOUS	1990?	30 - MIN
82	NIGHT IMAGE				
87	OCEAN CURRENTS				

This information is subject to change

GLOBAL DATA SET INFORMATION — 29 JANUARY 1992 — TABLE-1B

#	TITLE	THEME	SOURCE	DATE	RESOLUTION
98A	L&W AVE. MONTHLY AIR TEMP	ATMOSPHERE	LAND&SEA MEAS	1920 - 1980	10 - MIN
98B	L&W AVE.MONTHLY PRECIP.	ATMOSPHERE	LAND&SEA MEAS	1920 - 1980	10 - MIN
99A	ZOBLER SOIL TYPE	GEOSPHERE	MAPS	1986	1 DEGREE
99B	ZOBLER NEAR SURFACE SOIL TEXTURE	GEOSPHERE	MAPS	1986	1 DEGREE
99C	ZOBLER SOIL UNIT SURFACE SLOPE	GEOSPHERE	MAPS	1986	1 DEGREE
100	GEOSAT WAVE HEIGHT	HYDROSPHERE	GEOSAT	0[illegible]OV 86 -05 JAN 9	30 - MIN
101	VERT. MVT OF LANDMASSES	GEOSPHERE	COMP. MODEL	1991	1 DEGREE
104A	WMSSC CLIMATE (PRECIPITATION)	ATMOSPHERE	METEO STAT.	1731 - 1986	N/A
104B	WMSSC CLIMATE (TEMPERATURE)	ATMOSPHERE	METEO STAT.	1731 - 1986	N/A
104C	WMSSC CLIMATE (PRESSURE)	ATMOSPHERE	METEO STAT.	1731 - 1986	N/A
122A	GLOB. CIRC. MODEL (CHANGE TEMPERATURE)	ATMOSPHERE	MODELS	OVER 20 YEARS	30 - MIN
122B	GLOB. CIRC. MODEL (CHANGE PRECEPITATION)	ATMOSPHERE	MODELS	OVER 20 YEARS	30 - MIN
130	WORLD VEG. MAP (1985-87)	BIOSPHERE	AVHRR1,2	JAN 85 - DEC 87	10 - MIN
131A	GRID DATA OF THE WORLD TEMPERATURE	ATMOSPHERE	METEO STAT.	1951 - 1980	30 - MIN
131B	GRID DATA OF THE WORLD PRECIPITATION	ATMOSPHERE	METEO STAT.	1951 - 1980	30 - MIN
135	HISTORICAL SEA LEVELS	HYDROSPHERE	TIDE GAUGES	1862 - 1982	
138A	L&C MONTHLY TEMPERATURE	ATMOSPHERE	METEO STAT.	1930 - 1960	30 - MIN
138B	L&C MONTHLY PRECIPITATION	ATMOSPHERE	METEO STAT.	1930 - 1960	30 - MIN
138C	L&C MONTHLY CLOUDINESS	ATMOSPHERE	METEO STAT.	1930 - 1960	30 - MIN
139D	BIOME MODEL	BIOSPHERE			
140	TECTONIC PLATE BOUNDARIES	GEOSPHERE	MAGNETISM,ETC.	1986:UPDAT.IN 1991	
141	WATER VAPOR CONCENTRATION	ATMOSPHERE	DSMP SSM/I	JUL 87 - DEC 88	30 - MIN
143	TECTONIC PLATE RECONSTRUCTION	GEOSPHERE	VARIOUS	240,000,000 YRS	VAR.
152	EARTHQUAKES	GEOSPHERE	VARIOUS	FROM 21,000 BC	VAR.
153	SEA ICE CONC. (SMMR)	CRYOSPHERE	SMMR	NOV 78 - NOV 89	
160	TOM VAN SANTS WORLD IMAGE	BIOSPHERE	AVHRR		
167	POINT DATA ON DELTAS	HYDROSPHERE	VARIOUS		VAR.
168	HOT SPOT VELOCITIES	GEOSPHERE	VARIOUS	VARIOUS	VAR.
169	SLR VELOCITIES (PLATE MOTION)	GEOSPHERE	VARIOUS	1978 - 1986	VAR.

This information is subject to change

REGIONAL DATA SET INFORMATION — 29 JANUARY, 1992

TABLE-8A

#	TITLE	THEME	SOURCE	DATE	COVERAGE	RESOLUTION
1	CLOUD CLOUD DURATION FOR AFRICA	ATMOSPHERE	METEOS. TIR	SEPT.88-OCT.90	AFRICA CONTINENT (20W-50E,35N-35S)	7.6 KM
2	NO. OF RAINFALL DAYS FOR AFRICA	ATMOSPHERE	METEOS. TIR	SEPT.88-OCT.90	AFRICA CONTINENT (20W-50E,35N-35S)	7.6 KM
3	POTENTIAL EVAPOTRANSPIRATION FOR AFRICA	ATMOSPHERE	METEO.STAT.	1930-1990	AFRICA CONTINENT (20W-50E,35N-35S)	7.6 KM
8A	STRONG SAHARA DUST OUTBREAK	ATMOSPHERE	METEOS. TIR	28-30MAR.1985	NORT & NORTH-WEST OF AFRICA	10 and 15 KM
8B	STRONG DEPRESSION WEST OF PORTUGAL	ATMOSPHERE	METEOS. VIS	7-9APR.1989	E.ATLANTIC, IBERIAN PENINSULA,NW AFRICA	11 KM
9A	INTERPOLATED RAINFALL LATIN AMERICA	ATMOSPHERE	METEO.STAT.	1978-1990	LAT.AMER.(34N to 56S AND 119W to 34W)	10 - MIN
9B	INTERPOL. MEAN MONTHLY MAX TEMPERATURE	ATMOSPHERE	METEO.STAT.	1978-1990	LAT.AMER.(34N to 56S AND 119W to 34W)	10 - MIN
9C	INTERPOL. MEAN MONTHLY MIN TEMPERATURE	ATMOSPHERE	METEO.STAT.	1978-1990	LAT.AMER.(34N to 56S AND 119W to 34W)	10 - MIN
9D	MODAL ELEVATION FOR LATIN AMERICA	GEOSPHERE	MAPS	1991	LAT.AMER.(34N to 56S AND 119W to 34W)	10 - MIN
9E	FAO SOIL FOR LATIN AMERICA	GEOSPHERE	MAPS	1974	LAT.AMER.(34N to 56S AND 119W to 34W)	10 - MIN
14	EVAPOTRANSPIRATION (SW FRANCE)	BIOSPHERE	AVHRR,MAPS	16 JUNE 1986	SW FRANCE(43.167-45.333N AND 1.5W-1.5E)	1 KM
15	SURFACE TEMPERATURE (SW FRANCE)	ATMOSPHERE	AVHRR	16 JUNE 1986	SW FRANCE(43.167-45.333N AND 1.5W-1.5E)	1 KM
17	MONITORING OF POISON. ALGAL BLOOM SCAN.	BIO/HYDRO	AVHRR&TM	SPRING 1988	SKAGERRAK, SCANDINAVIA (58,88N 5,25E)	1 KM, 120 M
22	SEA COLOUR	BIO/HYDRO	CZCS	1979-1986	US W.COAST (20-56N,105-140W)	1 KM
28B	OZONE NORTH-POLE	ATMOSPHERE	NIMB-7 TOMS	NOV78-DEC90	ARCTIC	30 - MIN
28C	OZONE SOUTH-POLE	ATMOSPHERE	NIMB-7 TOMS	NOV78-DEC90	ANTARCTIC	30 - MIN
28A	OZONE, ANTARCTICA	ATMOSPHERE	HIRS/TOVS	26AUG-17SEPT.87	ANTARCTICA (30-90S)	1 DEGREE
29	NDVI FOR AFRICA	BIOSPHERE	AVHRR	SEPT.88-OCT.90	AFRICA (20W-50E AND 35N-35S)	7.6 KM
40	VEG./LAND USE, SW FRANCE	BIOSPHERE	AVHRR	16 JUNE 1986	SW FRANCE(43.167-45.333N AND 1.5W-1.5E)	1 KM
44	CORINE	VARIOUS	MAPS		EEC	VARIOUS
50A	NDVI CONTINENTAL (TUCKER-GAC)	BIOSPHERE	AVHRR	1981+	CONTINENTS	4 KM
50B	NDVI CONTINENTAL (TUCKER-GAC)	BIOSPHERE	AVHRR	1981+	CONTINENTS	4 KM
50C	NDVI CONTINENTAL (TUCKER-GAC)	BIOSPHERE	AVHRR	1981+	CONTINENTS	4 KM
50D	NDVI CONTINENTAL (TUCKER-GAC)	BIOSPHERE	AVHRR	1981+	CONTINENTS	4 KM
50E	NDVI CONTINENTAL (TUCKER-GAC)	BIOSPHERE	AVHRR	1981+	CONTINENTS	4 KM
57A	SEA ICE CONCENTRATION, NORTH POLE	CRYOSPHERE	DMSP/SSMI	JUL 87-MARCH 89	NORTH POLE (45 to 90 DEG.)	25 KM
57B	SEA ICE CONCENTRATION, SOUTH POLE	CRYOSPHERE	DMSP/SSMI	JUL 87-MARCH 89	SOUTH POLE (45 to 90 DEG.)	25 KM
60	FOREST MAPPING IN BAVARIA	BIOSPHERE	MSS,TM,SPO	APRIL84-JUN87	GERMANY (48.8-49.0BN and 11.85-12.0BE)	30M,TM
63	FOREST COVER CHANGE IN MENGLUN	BIOSPHERE	MSS,TM	3MAR73-2FEB88	CHINA (21.83-22N AND 101.08-101.5E)	TM30M,MSS80M
75	SEA-SURF. TEMP, EQUAT. PACIFIC	BIO/HYDRO	AVHRR	1982-1989	EQUAT.PACIFIC (20N-20S,70-150W)	30 - MIN
77	URBAN DEFORESTATION ZAIRE	BIOSPHERE	MSS	6SEP73 + 9SEP88	LUBUMBASHI, ZAIRE (11.67S AND 27.5E)	72.27 M
80	RANGELAND MONITORING IN SOUTH ALBERTA	BIOSPHERE	MSS	27SEP73-22SEP88	SOUTH. ALBERTA (60-49.7N and 112-110E)	50 M
91	MONTREAL URBAN GROWTH	CIVILIZATION	MSS	5SEP72-17JUL82	MONTREAL (CENTRED AT 45.5N 74.6W)	50 M
94	VEGETATION INDEX IN USA	BIOSPHERE	AVHRR	MAY TO AUG 1990	U.S.(48 STATES) (65-125W AND 25-50N)	0.625 MIN
102A	LAND DEGRADATION IN AFRICA	GEOSPHERE	VARIOUS		AFRICA	10 - MIN
102B	LAND DEGRADATION IN AFRICA	GEOSPHERE	VARIOUS		AFRICA	10 - MIN

This information is subject to change

REGIONAL DATA SET INFORMATION — 29 JANUARY, 1992 — TABLE-2B

#	TITLE	THEME	SOURCE	DATE	COVERAGE	RESOLUTION
110	NDVI NORTH AMERICA	BIOSPHERE	AVHRR	11-20 AUG. 1990	NORTH AMERICA	1 KM
118	NDVI CAN. LAND COVER	BIOSPHERE	AVHRR	1988 and 1989	PROV. OF CAN. AND SOUTH OF TERRITORIES	1 KM
121	OCEAN-SURF. ELV. GULF OF ALASKA	HYDROSPHERE	GEOSAT	8NOV86-7JUN88	GULF OF ALASKA,45-60N,120-150W	4 KM
123	OCEAN COLOR, BC COAST & OFFSHORE	BIO/HYDRO	CZCS	MAR.-SEPT 1979	W COAST BC,(48.25-55.25N,121.83-138.17W)	2 KM
139	SEA SURFACE TEMP. (JAPAN)	HYDROSPHERE	MOS1 VTIR	SPR/SUM/WIN 90	JAPAN ISLAND (22-47N and 120-150E)	2.7 KM
134	ICE MOTION IN ANTARCTIC	CRYOSPHERE	MOS1 VTIR	12 SEPT. 89	ANTARCTICA	1 KM
136	USSR DATA (ARAL SEA?)					
137	RED TIDE, WEST COAST OF CANADA	BIO/HYDRO	AVHRR	24AUG-29SEPT 90	S.BC COAST (48.5-51.3N,122.5-129.5W)	1 KM
139	N. ATLANTIC PRODUCTIVITY DATA	BIO/HYDRO	CZCS	JAN.-DEC.1979	NORTH ATLANTIC (20S-70N,1E-89W)	1 DEGREE
142A	SPOT IMAGES, VARIOUS	VARIOUS	SPOT	VARIOUS	VARIOUS	20 or 10 m
142B	SPOT IMAGES, VARIOUS	VARIOUS	SPOT	VARIOUS	VARIOUS	20 or 10 m
142C	SPOT IMAGES, VARIOUS	VARIOUS	SPOT	VARIOUS	VARIOUS	20 or 10 m
142D	SPOT IMAGES, VARIOUS	VARIOUS	SPOT	VARIOUS	VARIOUS	20 or 10 m
142E	SPOT IMAGES, VARIOUS	VARIOUS	SPOT	VARIOUS	VARIOUS	20 or 10 m
144	MILK RIVER (MSS)	BIOSPHERE	MSS	9 OCT 1982	USA-CAN Border AT SOUTHERN ALBERTA	79 m
145	SPUCE BUDWORM OUTBREAK	BIOSPHERE	TM,MSS	AUG.78+JUL.78,90	CAPE BRETON ISLAND,NOVA SCOTIA,CAN.(?)	30m
149	QUAD 3 PEACE RIVER	BIOSPHERE	TM	19 JULY 84	PEACE RIVER ALBERTA, CANADA	30m
148	JAMES-BAY (MSS)	HYDROSPHERE	MSS		JAMES-BAY QUEBEC	
154	WADDEN SEA, WEST COAST GERMANY	HYDROSPHERE	TM	84/4/25+88/5/25	NORTH SEA COAST IN GERMANY	30 m
155	MAUNA LOA CARBONE DIOXIDE	ATMOSPHERE	AIR SAMPLES	58/3/1-88/12	19N,155W	N/A
156	UNESCO RIVER DISCHARGE	HYDROSPHERE		1807-1972	AFR.,S.AMERICA,ASIA,EUROPE,OCEANIA,etc.	N/A
157	CANADA NDVI TIME SERIES	BIOSPHERE	AVHRR	20APRIL-20SEP88	CANADA	1 KM
158	PSEUDO NAT.COLOUR CAN. (NDVI)	BIOSPHERE	AVHRR		CANADA	
161A	VARIOUS NIGHT IMAGES	CIVILIZATION	DSMP	88-89-91	SAHEL, NORWAY AND E. SEABOARD AMER.	0.6 and 2.6 km
161B	VARIOUS NIGHT IMAGES	CIVILIZATION	DSMP	88-89-91	SAHEL, NORWAY AND E. SEABOARD AMER.	0.6 and 2.6 km
161C	VARIOUS NIGHT IMAGES	CIVILIZATION	DSMP	88-89-91	SAHEL, NORWAY AND E. SEABOARD AMER.	0.6 and 2.6 km
162	MACKENZIE DELTA	HYDROSPHERE	MSS/TM?		MACKENZIE DELTA IN CANADA	
169	FOREST FIRE IN BC	BIOSPHERE	TM	18 AUGUST 1985	(BRITISH COLUMBIA, CANADA	30 m
169A	HUBBARD GLACIER	CRYOSPHERE	TM	15 JULY 1985	SOUTH-WEST OF ALASKA (USA)	30 m
169B	HUBBARD GLACIER	CRYOSPHERE	TM	11 SEPT. 88	SOUTH-WEST OF ALASKA (USA)	30 m
169C	HUBBARD GLACIER (FIRST COMPONENT)	CRYOSPHERE	TM	15 JULY 1985	SOUTH-WEST OF ALASKA (USA)	30 m
169D	HUBBARD GLACIER (FIRST COMPONENT)	CRYOSPHERE	TM	11 SEPT. 88	SOUTH-WEST OF ALASKA (USA)	30 m
169E	KLUANE GLACIER	CRYOSPHERE	TM	15 JULY 1985	KLUANE NAT.PARK (YUKON TERRITORY CAN)	30 m
169F	KLUANE GLACIER	CRYOSPHERE	TM	27 AUGUST 1991	KLUANE NAT.PARK (YUKON TERRITORY CAN)	30 m
169G	WHITE AND THOMPSON GLACIERS	CRYOSPHERE	AIR PHOTO	AUGUST 1959	NW TERRITORIES CAN. (79.42N, 94W)	13.2 m
169H	WHITE AND THOMPSON GLACIERS	CRYOSPHERE	SPOT HRV2	17 MAY 1988	CENTRE SCENE LAT:79.28N, LONG:-80.13	10 m
169	TIMBER HARVEST IN BC	BIOSPHERE	TM		(BRITISH COLUMBIA	20 m
202	ESTIMATED RAINFALL FOR AFRICA	ATMOSPHERE	TIP	9+10/88-9+10/89	AFR.,SAHELIAN REGION (0-35N and 35W-46E)	7.6 KM

TABLE 3: BASIC FUNCTIONS OF THE ENCYCLOPEDIA

DATA MANAGEMENT
- installation of diskette files;
- download of selected data sets from CD-ROM to hard disk;
- transformation of data sets into various map projections.

DATA DISPLAY
- display on the screen of all data types;
- zoom and roam;
- frame-grab capture of displayed data;
- automatic replay and animation.

HYPERMEDIA
- script create/play
- button tools
- text editor

DATA MANIPULATION
- vector edit tools (chain entry and networking, polygonization,...)
- mask generation;
- 3-D representation.

POINT QUERY
- point queries from multiple data layers and buffer zone queries.

DATA QUERY
- profiles of multiple data layers (including time series data representation);
- histograms of multiple data layers;
- scattergrams from two data layers.

FILE ANALYSIS
- calculation of area;
- extraction of image and map statistics from polygons;
- image and map regrouping;
- image and map arithmetic;
- map overlay;
- image and map rescale;
- buffer zone.

DATA INPUT/OUTPUT
- import/conversion of DCW vector data;
- export/conversion of data sets to ASCII files and to binary files for use outside the Encyclopedia;
- plotting of displayed images and maps on optional printers.

Some Basic Issues in the Development of a Land Information Infrastructure

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Within British Columbia, the Land Information Infrastructure is being developed to provide a variety of data access services to users of geomatics data throughout the province. The data itself will reside in a number of federated databases. This raises issues related to accessing and understanding the data.

Two particularly important questions are as follows. How can the data be universally described, given that it resides in different propietary environments? How can queries be constructed, interpreted, and answered given that they must be able to address a number of geographic concepts?

The technical solutions require the development of:

i. a semantically rich, language able to handle diverse geographic structures,
ii. extensions to SQL which can address geographic relationships,
iii. translation capabilities associated both with the queries and the data, and
iv. protocols and services for handling the queries and data.

This paper reviews the progress in British Columbia on the LII with particular reference to these issues.

Quelques questions de base sur le développement d'une infrastructure d'information sur le territoire.

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En Colombie-Britannique, l'infrastructure d'information sur le territoire est en développement afin d'offrir un ensemble de services d'accès aux usagers de données géomatiques de toute la province. Les données seront entreposées dans une série de bases de données fédérées. Cette caractéristique soulève des questions sur les droits d'accès et sur la bonne compréhension des données.

Deux questions particulièrement importantes se posent. De quelle façon les données peuvent être universellement décrites, sachant qu'elles résident sous différents systèmes? De quelle façon peut on construire des requêtes, les interpréter et y répondre sachant quelles doivent permettre d'aborder un grand nombre de concepts géographiques?

Les solutions techniques requièrent le développement de:

i. un langage sémantiquement riche, capable de manipuler diverses structures géographiques,
ii. des extensions au SQL qui peuvent supporter les relations géographiques,
iii. des capacités de traduction associées aux requêtes et aux données.
iv. des protocoles et services pour la manipulation de requêtes et de données.

Cette communication présente l'état des progrès de l'infrastructure d'information sur le territoire en Columbie'Britannique, avec un accent particulier sur ces questions.

ONTARIO MINISTRY OF NATURAL RESOURCES

MODEL DISTRICT GIS PROJECT : RESULTS AND EXPERIENCES

By: Darko I. Poletto, John Houweling, Trevor Bain
Ontario Ministry of Natural Resources

ABSTRACT

In 1988 the Ontario Ministry of Natural Resources (MNR) embarked on a GIS model project. The goal of the project was to develop an operational GIS to support integrated resource management and decision support in representative northern and southern Ontario MNR district offices. The project was completed in the fall of 1991, with project expenditures totalling $4.9 million Canadian. The benefit/cost ratio for implementation was found to be 2:1. This paper presents some of the project results, observations and recommendations.

Projet de modèle de SIG régional du MRN: résultats et expériences

RÉSUMÉ

En 1988, le ministère ontarien des Ressources naturelles (MRN) a lancé un projet de modèle de SIG. Le but du projet était de mettre au point un SIG opérationnel de soutien à la gestion intégrée des ressources et à la prise de décisions dans les bureaux régionaux représentatifs du nord et du sud de l'Ontario. La projet a été réalisé à l'automne 1991, les dépenses totalisant 4,9 millions $ canadiens. Le rapport avantages/coût de mise en oeuvre a été de 2/1. Le présent article renferme quelques résultats, observations et recommandations relatifs au projet.à

INTRODUCTION

The release of "MNR: Direction' 90s", a blueprint document for resource management, outlined three major strategies to guide MNR activities in the 1990s. They are:

1) Seeking out partnerships in resource management.

2) Valuing resources.

3) Improving the knowledge base.

These strategies are also designed to support MNR's central goal: that of contributing to the environmental, social and economic well-being of Ontario through the sustainable development of natural resources. The Brundtland Commission describes sustainable development as development that meets the needs of today's society without compromising the ability of future generations to meet their needs. One of the keys in promoting sustainable development is timely access, efficient management and analysis of geographical data. The information age has introduced many new technologies that can be used in performing these functions.

One of these tools is a Geographic Information System (GIS). GIS is a system of computer hardware, software and procedures designed to support the capture, management, analysis, modelling, and display of geographically referenced data.

MNR IN 1988

To carry out the Ministry operational mandate and policies, staff require access to very large volumes of geographic data on all natural resources. There are many problems with the present way that MNR collects, manages and uses geographic data. District staff are finding it increasingly difficult to work efficiently and effectively due to problems with the:

- lack of data standards
- volume of data
- lack of quick access to data
- currency of data
- ability to undertake geographic analysis
- meaningful display of data

MNR MODEL DISTRICT GIS PROJECT

To address MNR problems with geographic data handling and assess the full potential of GIS, MNR identified a need for a comprehensive model project. The project had the following objectives:

1) Implement a district GIS in order to improve:

- the accessibility of resource data to managers
- customer service
- the decision making process
- the ability to influence land use decisions

2) Evaluate:

- the benefits and potential of GIS for MNR
- the impact of sharing digital resource data with other agencies
- the impact of GIS technology to MNR

3) Demonstrate various district GIS applications.

PROJECT SITES

In the spring of 1988, the Model project was initiated in the Cambridge and Timmins district offices. These two sites were chosen using the criteria of availability of digital Ontario Basic Mapping (OBM) program data, differences in Ontario's physiography, types of land ownership, reduction of measurement bias and the district staff's experience with GIS.

HUMAN RESOURCES

In each district, the project team included a Project Manager, a Team Leader and one or two technical/administration support personnel. Outside consultants and the MNR GIS Applications and Technology Transfer Unit (GATT), helped with implementation and end-user training and support. The team had full responsibility for the system development and implementation.

PROJECT SCOPE

The Model project identified 33 GIS applications which fall within eight MNR program areas: lands administration, forestry, wildlife, forest fire management, parks, planning, aggregates and fisheries. These applications use one or more of 48 resource inventories that comprise the program area data sets. The inventories cover an area of approximately 7000 square kilometres in each district. The applications are designed to act as decision support tools and/or geographic information management tools in support of MNR's seven generic business functions:

1) perform resource management
2) perform private and Crown land management
3) prevent/resolve user conflicts or issues
4) issue authority to use or consume a natural resource
5) provide private land management
6) respond to inquiries and disseminate information
7) store, maintain and retrieve resource data.

PROJECT RESULTS

By September 1991, the Model project had fulfilled all of its objectives. The overall system is called the Spatial User Interface (SUI). SUI is a GIS application tool which provides a user-friendly mechanism by which all geographic and tabular data, applications and geographic data manipulation tools are accessible to all authorized system users. SUI consists of two sub-systems: the 'Interactive User Interface (IUI)' and the 'Map Composer (MC)'. The IUI is designed strictly for fast queries and analysis. The MC has all the functionality of the IUI, but also allows the user to compose a map product, complete with legends, scale bar, notes, etc.

Each GIS application is composed of one or more of the following five functions:

i) Geographic data classification/selection - designed to allow for identification and tagging of graphic data based on a user specified classification schema;

ii) Tabular data input - designed to allow for the input of geographic entity attribute data via data input screens and forms;

iii) Tabular data editing and updating - designed to allow for editing and browsing of geographic entity attribute data via data forms;

iv) Tabular data reporting - designed to allow for the generation of pre-defined geographic entity attribute data reports; and

v) Geographic data reporting - designed to allow for the generation of pre-defined geographic entity data reports.

Table 1 lists each of the Model project applications implemented and identifies which of the above described functions is available. The table is meant to provide a summary of the application functionality available to the user community. The tabular and graphic data reporting functions utilise various spatial and DBMS operators to generate pre-defined reports. These processes constitute the fixed-hard coded system analysis capability.

In addition to the hard coded analysis capability, the system also allows the user to perform spatial analysis in an interactive fashion, utilising generic spatial functions. The user has the ability to measure distances and areas, to determine position, identify and select features for map composition or display based on specified criteria and characteristics. Table 1 also summarizes, by application, the map display, query and composition functions - of which the three most important are:

i) **display/map selected geographic entities**: Geographic entities from any of the topographic or thematic data layers that define the district geographic database can be displayed to the screen (IUI) or brought into a map composition (MC);

ii) **identify features**: This function is designed to allow for the identification or description of a geographic entity from any of the topographic or thematic data layers that define the district geographic database; and

iii) **query**: Some or all of the geographic entities from any of the topographic or thematic data layers that define the district geographic database are retrieved and displayed. Selection of these entities is based on the results of a user specified ad-hoc query. The query is posed using an interactive graphic query builder tool which allows for logical and relational operators to be used.

TABLE 1: MNR MODEL DISTRICT GIS: APPLICATION FUNCTIONAL SCOPE

APPLICATION	1	2	3	4	5	6
FISHERIES						
Fisheries Mgmt Plan	Y	Y	Y	Y	Y	A/B/C
Maintain Fisheries data	Y	Y	Y	Y	Y	A/B/C
FORESTRY						
5 Year Operations Plan	N	N	N	N	Y	N
Maintain Forestry Data	N	Y	Y	N	Y	A/B/C
Priorize Private Land	N	N	N	N	N	N
LANDS ADMINISTRATION						
Land Status Index	N	Y	Y	Y	Y	A/B/C
Waste Disposal Sites	N	N	N	N	N	A/B/C
Prepare Lake Plans	N	N	N	N	N	A/B/C
PARKS						
Construction Tra[illegible]	Y	Y	Y	N	Y	A/B/C
Parks Facilities Maint.	Y	N	Y	N	N	A/B/C
Park Boundary Maps	Y	N	N	N	N	A/B/C
Administer Conserv. Land Tax	N	N	N	N	N	N
RES. LIASION/PLANNING						
Plan Input and Review	Y	Y	N	Y	N	A/B/C
IRM within the District	Y	Y	Y	Y	Y	A/B/C
Disseminate R.M. Information	Y	Y	Y	Y	Y	A/B/C
Fossil Fuel Maps	Y	Y	Y	Y	N	A/B/C
District Land Use Guidelines	Y	N	N	Y	Y	A/B/C
WILDLIFE						
Wildlife Inventories	Y	Y	Y	Y	Y	A/B/C
Traplines	N	Y	Y	Y	N	A/B/C
OPERATIONS						
Lakes & Rivers Improv. Act	Y	Y	Y	Y	Y	A/B/C
Inspect Watercourse Alt.	N	N	N	N	N	A/B/C
Maintain Roads Inventory	Y	Y	Y	Y	Y	A/B/C
AGGREGATE RESOURCES						
Pits & Quarries Inventory	Y	Y	N	N	Y	A/B/C
Administer Waysides	Y	Y	N	N	Y	A/B/C
FIRE MANAGEMENT						
Fire History	N	Y	Y	Y	N	A/B/C
Forest Fuel Rating	Y	N	N	N	N	A/B/C
Prescribed Burns	N	N	N	N	N	A/B/C

LEGEND

Y - YES FUNCTION IS AVAILABLE
N - NO, FUNCTION IS NOT AVAILABLE
1 - GEOGRAPHIC DATA CLASSIFICATION/SELECTION FUNCTIONS
2 - TABULAR DATA INPUT FUNCTIONS
3 - TABULAR DATA EDITING AND UPDATING FUNCTIONS
4 - TABULAR DATA REPORT GENERATORS
5 - GEOGRAPHIC DATA REPORT GENERATORS (CUSTOM REPORTS)
6 - INTEGRATED INTO SUI
A - MAP ALL/SELECTED FEATURES
B - IDENTIFY FEATURES
C - MAP FEATURE(S) BY QUERY SELECTION

PROJECT COSTS

The project implementation costs were $4.9 million and are broken down into six categories as presented in Table 2 and Fig. 1. The biggest cost was for data preparation and entry, and includes the cost of acquiring the OBM topographic data, Forest Resource Inventory (FRI) and Crown Land Parcels data. These data sets are being compiled as part of the Ministry's data infrastructure (corporate data), designed to serve many public and private sector clients, and represent a cost of $1.5 million. Since this cost would be incurred by the MNR regardless of the project, it can be argued that the true project cost is $3.4 million.

To maintain this capital investment, additional on-going funding is required. The estimated level of on-going funding to support and maintain the system is $0.2 million per annum per district. However, this does not include the data maintenance costs.

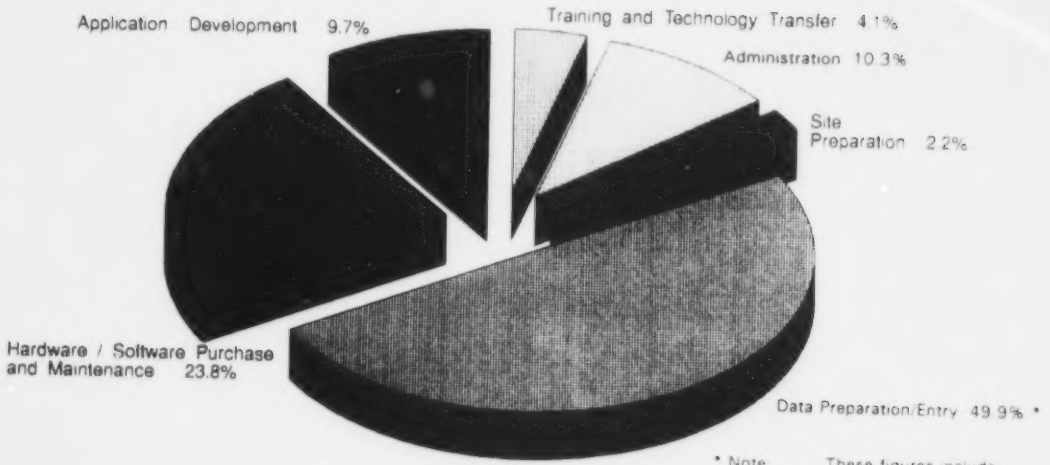
Table 2: MNR Model District GIS Project - Start-up Costs
(in dollars)

	Cambridge	Timmins	Project Total
Project Costs			
Salaries & Wages	476,700	736,400	1,213,100
Administration	125,000	96,500	221,500
Hardware/Software Purchase	549,900	492,800	1,042,700
Hardware/Software Maintenance	62,700	74,700	137,400
Site Preparation	56,600	53,100	109,700
Technical Supplies	13,300	21,300	34,600
Data Preparation	87,600	5,800	93,400
Data Entry/Digitizing	237,600	60,600	298,200
Applications Development	42,900	59,500	102,400
GATT Staff (Applications Development)	63,500	63,500	127,000
Technology Transfer	17,000	24,000	41,000
Training	16,000	49,000	65,000
Total Project Costs	1,748,800	1,737,200	3,486,000
Corporate Data Acquisition Costs			
OBM *	686,600	212,900	899,500
FRI *	220,000	215,700	435,700
Crown Land Parcels	6,000	134,600	140,600
Total Corporate Data Acquisition Costs	912,600	563,200	1,475,800
TOTAL	2,661,400	2,300,400	4,961,800

* - Reflects the cost of digitizing from existing hardcopy maps

As part of the project evaluation a benefit/cost analysis was done. The ratio for implementing GIS was found to be approximately 2:1, which means that the benefits derived from the implemented system are worth twice the costs given a ten year time frame for payback on investment.

Fig. 1: GIS Activities as Percentage of Total Start-up Costs



* Note: These figures include Corporate Data Aquisition Costs (i.e. OBM, FRI and Crown Land Parcels)

PROJECT ISSUES

The following section is taken from the Model project report, and documents the major issues that were faced throughout the project. A number of observations and recommendations are made, reflecting the projects knowledge and experiences. Although the discussion is specific to MNR, the issues are generic and are relevant to any organization.

A. Information Resources

A.1. Data

A pillar of sustainable development is the quality and accuracy of the data upon which decisions are made. Therefore, data must be considered as one of the organization's greatest assets and must be appropriately managed.

There was a vast amount of time and effort spent on populating the GIS databases (geographic and tabular). This was mainly a result of the added effort on the part of staff to resolve errors and deficiencies in the existing data sets. In order to ensure that the results of GIS analysis are relevant, data must be of acceptable quality and be up-to-date. It was also discovered that most end-users did not have sufficient time to under take the tedious task of data preparation and entry. Furthermore, for some corporate data that were available, their utility was found to be inadequate given differences in the north and south requirements. For example, the FRI data for Cambridge was lacking the required detail, thus necessitating additional work to be undertaken.

The cost of establishing the GIS databases was found to be half of the total project expenditures ($2.48 million). Even though this amount is substantial, it must be recognized that the cost of conversion is only $1.24 M or 50% of this total. The remainder reflects the cost of bringing the data to the required level of quality.

RECOMMENDATION: Where appropriate, MNR must re-evaluate its data requirements with respect to its sustainable development goal, new resource management practices and client needs.

RECOMMENDATION: MNR must develop innovative cost sharing initiatives with partners and clients.

RECOMMENDATION: The cost of data collection and management is a cost of doing business and, therefore, should not be charged to GIS implementation.

RECOMMENDATION: MNR must re-engineer, where it is deemed appropriate, its data collection methodology in order to satisfy its business requirements.

RECOMMENDATION: Further work in developing specific Model project applications and databases be limited only to those programs that have an immediate and proven need that cannot be satisfied by any corporate initiative.

A.2. Data Standards

Standards must be set to assure uniformity within a single data set or across data sets. Data capture should be undertaken in standardized ways that will assure the widest possible use and consistency of the information. The Model project developed a number of interim data standards.

Without corporate data standards, the portability and utility of MNR's databases is questionable. Standardization of data and databases is critical to enable accessibility by internal and external clients seeking data at varying organizational levels. Once set, MNR staff can begin to clean their existing data to the standards prior to any further GIS initiatives.

RECOMMENDATION: MNR must develop data standards and a corporate data dictionary to facilitate the building of information systems.

RECOMMENDATION: MNR must set up an appropriate organizational structure to develop and ensure compliance with corporate data standards.

RECOMMENDATION: MNR review all data standards developed for the Model project and assess their corporate utility.

A.3. Data Dissemination Policy and Liability

A number of data dissemination and liability issues surfaced during the project. These included: protecting the legal rights of all parties concerned; controlling access and the use of data; complying with the Freedom of Information and Protection of the Privacy Act; and assuming responsibility for corrupted or erroneous data. To address some of these issues the Model project formed a working group. The findings of the group point to a need for corporate policy development.

RECOMMENDATION: There is an immediate need to establish a government-wide digital data dissemination policy.

A.4. Data Update Procedures

The emphasis of the project was to establish specific geographic and tabular databases required for the implemented applications. These databases are "snap shots" in time and can be perceived to be current due to their digital nature. The databases also represent a significant capital investment to the organization.

RECOMMENDATION: MNR must develop and institute comprehensive data updating procedures that are sensitive to the integrated nature of all the natural resource data.

RECOMMENDATION: The responsibility for data management and maintenance must reside with the appropriate user at source.

A.5. Data Integration

GIS technology has the ability to integrate disparate data sets compiled and represented at varying scales. Given this functionality, the user must be cognizant of the implications of data integration. Specifically, the accuracy and fidelity of the resultant information must be known and included in the decision making process.

RECOMMENDATION: MNR's data integration strategies must be based upon the nature of the decisions and the data quality, rather than solely their technical feasibility.

B. Human Resources

B.1. Staffing

GIS implementation is a complex task requiring a diverse set of skills and expertise which need to be managed. The required skill sets will consist of team members who have appropriate business and technical knowledge. The technical knowledge for GIS implementation at each district/area office will provide the following functions: client support, standards adherence, client training, and systems maintenance. It should be noted that skilled human resources in GIS are not readily available at present throughout North America.

To assist GIS implementation, end users may be divided into two groups: the majority who are able to use a customized GIS and a small group of super-users who are familiar with the vendor's GIS toolbox. This second group would form the first level of GIS support. If issues cannot be solved by this group they would be elevated to the GIS expert in each district.

RECOMMENDATION: Appropriate experts from the user community must be dedicated to system development with a corresponding adjustment in their workload.

RECOMMENDATION: Job descriptions for MNR employees must include the appropriate level of information technology literacy required to deliver their respective duties and tasks.

RECOMMENDATION: Each District/Area office interested in implementing GIS must designate a number of staff to be trained as super-users.

RECOMMENDATION: Each District/Area office interested in implementing GIS must include staffing positions for an Applications Specialist and a Systems Support Officer.

RECOMMENDATION: MNR must investigate recruiting technically competent staff from non-traditional sources in addition to internal training initiatives.

B.2. Staff Training

The GATT Unit developed a GIS course designed to teach the MNR resource technicians GIS concepts. The project identified additional training needs but these could not be satisfied with the available resources and the given time frame.

RECOMMENDATION: MNR must develop a strategic GIS education and training plan utilizing the knowledge and experience gained in the Model project.

RECOMMENDATION: MNR should investigate the feasibility of forming partnerships with Universities, Colleges and private industry for GIS education and training.

C. Technical

C.1. Hardware

Based on the project data management and application processing requirements, the hardware solution selected would be dramatically altered if chosen today. The intensive computing power required for GIS necessitates a much more powerful hardware solution. Most GIS vendors today have or are in the process of providing such solutions.

RECOMMENDATION: MNR test recent hardware technologies when selecting the corporate system for GIS.

RECOMMENDATION: Detailed hardware capacity plans must be developed prior to full scale GIS implementation.

RECOMMENDATION: MNR must develop a consolidated and rationalized approach to hardware purchases for GIS in order to minimize costs and maximize efficiency.

C.2. Software

Overall, the GIS software selected for the project performed well. However, there were difficulties encountered with specific functions. This created delays in developing the required system.

RECOMMENDATION: A comprehensive GIS software selection strategy must be developed for the MNR in order to identify the optimal software solution.

RECOMMENDATION: The corporate GIS solution must include an interface to the Ministry standard RDBMS to ensure integration with other information systems.

C.3. GIS Applications and Spatial User Interface

The users' responses regarding the quality of the developed applications and SUI can provide a good indication of how successful the project was in:

i) understanding the user program functional requirements and transforming them in to automated procedures;

ii) gaining user acceptance of GIS technology as a data management and/or decision support tool;

iii) developing a GIS application model for integrated natural resource data management and analysis; and

iv) exploiting information technology as an aid in solving MNR's information management problems.

The user community responded very favourably to the implemented applications and SUI.

RECOMMENDATION: MNR must undertake a structured and comprehensive approach to developing GIS utilizing existing knowledge and proven solutions.

RECOMMENDATION: MNR review the Model project GIS applications and SUI to ascertain their corporate applicability.

C.4. System Security

In a shared system, different parts of the database will belong to different users. In this environment, it is important to control the system activities of the users. System security is used to protect the database against unauthorized disclosure, alteration, or destruction.

RECOMMENDATION: MNR must develop appropriate system security plans and measures prior to full scale GIS implementation.

C.5. Networking

A multi-site GIS requires a robust telecommunications network. This enables the development of systems within a corporate environment, and allows for de-centralized computing and data storage. The benefits will include: flexibility, data integrity and data rollup.

RECOMMENDATION: GIS requirements must be included in telecommunications network planning.

C.6. System Documentation

Documentation should be the natural, working by-product of systems development. It is the only mechanism by which systems can be maintained, enhanced and properly utilized. The project developed its own interim documentation standards.

RECOMMENDATION: MNR must develop a comprehensive set of system and user documentation standards.

RECOMMENDATION: MNR assign organizational responsibility to IRD for asserting and enforcing compliance to documentation standards.

D. Communications

A GIS communication strategy provides the mechanism by which the experiences and knowledge gained from the project are conveyed to the rest of the organization. This will ensure that maximum benefit is obtained from the investment. Furthermore, it is a vehicle through which MNR can manage user expectations.

RECOMMENDATION: MNR should develop a GIS communications plan that would include a video outlining the project system and experiences.

RECOMMENDATION: MNR must ensure that all GIS initiatives utilize the knowledge and experience gained in the Project.

E. Management

E.1. System Development Life Cycle

The project employed a prototyping method of system development. This involved the scoping of applications into very manageable components that could be developed and implemented in a very short time period (2 to 4 months). While allowing rapid systems development, this methodology can lead to a narrow view of the organization's business requirements. To overcome this problem, a comprehensive system development life cycle (SDLC) approach should be utilized.

A SDLC is a project management tool, used to plan, execute, and control system development projects. The SDLC consists of four phases: systems analysis, systems design, systems implementation, and systems support. Each phase needs to be carefully and fully developed before subsequent phases are considered. This phased approach offers a structured methodology to building systems and overcomes the 'haphazard manner' of systems implementation. Additionally, it provides several decision opportunities and a chance to re-evaluate the cost-effectiveness of the proposed system.

RECOMMENDATION: MNR must adopt a systems development methodology that encompasses fully the system development life cycle.

RECOMMENDATION: Since systems are capital investments, they must be priorized and economically justified.

E.2. Corporate vs. Local Systems

The resources required for system building are tremendous. Local initiatives can be very successful in meeting specific local requirements. However, their applicability to other parts of an organization is often questionable. Given the size of MNR and its operational mandates, most resources should be channelled towards corporate systems initiatives. This is the only way that MNR can develop comprehensive systems and realise cost savings from economies of scale. Furthermore, it is only through corporate initiatives that all of the Ministry's concerns will be taken into account and properly incorporated.

The initial Model project view of the system contained a localized definition of the MNR business requirements. Subsequent analysis found a number of components which were common to each program area in the north and the south.

RECOMMENDATION: System development within MNR must undertake a comprehensive analysis of its business requirements prior to the development of any localized systems.

RECOMMENDATION: IRD evaluate the project system as part of an interim solution to its GIS requirements.

E.3. Benefit-Cost

The Model project results show that the benefit of implementing a GIS exceeds the costs by a factor of approximately 2:1 given a ten year time frame for a return on investment. It should be noted that there are additional qualitative benefits not included in this factor.

Based upon the Model project experiences, it is estimated that provincial cost for GIS implementation would be approximately $300 per square kilometre for a system of similar scope. Note, this figure does not include the cost of applications development as this cost would be borne corporately and is applicable to the whole organization. In addition, the final cost of implementation must consider the following factors:

i) economies of scale in systems development and project management;

ii) consolidation, standardization and rationalization of hardware and software;

iii) partnerships in database development;

iv) utilization of alternate technologies (e.g. remote sensing); and

v) training to support the full range of GIS users within MNR.

RECOMMENDATION: Given the high cost of GIS implementation, MNR must re-assess all outstanding initiatives and determine their cost effectiveness prior to any additional funding.

RECOMMENDATION: All new GIS initiatives must be cost justified and priorized according to corporate versus local needs and interests.

RECOMMENDATION: Where it is deemed appropriate, all outstanding and new initiatives utilize the knowledge, experience and applications components of the Model project system in order to maximize cost savings and minimize duplication.

E.4. Institutional Issues

GIS technology will be moving into an environment with its own organizational structures and corresponding issues and agendas. As an integrating technology, GIS is more likely to require organizational changes than other technological innovations. This creates a need for institutional change, i.e. breaking down of organizational barriers. However, organizational change is often difficult to achieve and can lead to failure of the GIS project. These issues are more often reasons for failure of GIS projects than technical issues.

Institutional problems include:

i) Overemphasis on the technology planning without due consideration of longer term management issues. This can lead to non-recognition of the necessary changes to an organizational structure and its operational procedures;

ii) Lack of will by organizational units to interact and exchange data;

iii) Lack of adequate decision making organizational structures;

iv) Lack of system support staffing. A multi-user GIS requires a strong presence of technically competent staff. It is important to stay away from the temptation by management to fill these positions from existing staff without adequate attention to qualifications; and

v) Lack of recognition that the integration process offered by GIS is not strictly a technical data issue, but also an institutional one.

vi) The requirement to manage user expectations. A GIS is often seen as a panacea for all our geographic data capture, management, display, analysis and modelling requirements. However, the feasibility and usefulness of these solutions needs to be considered in light of user needs, available resources and a cost/benefit.

RECOMMENDATION: Institutional issues must be addressed by MNR through the change management process and in the information technology implementation initiatives.

RECOMMENDATION: MNR must develop a GIS Implementation Strategy and Action Plan to address all institutional problems and recommendations made in this report.

CONCLUSION

As a service provider, MNR has an obligation to promote public involvement in its activities and to develop partnerships with related organizations. however, time and technology constraints have limited the extent to which this has actually occurred. With the Model project, MNR now has some of the necessary tools to nurture partnerships in resource management by making it possible to provide and share information more effectively.

The Model project also provides a more efficient way of valuing resources. The improved data management and geographic analysis provide MNR with the necessary tools to assess the impact of using natural resources. This will ensure a viable natural resource base for future generations.

To improve MNR's knowledge base, the Model project can help define and clearly describe the location of resource values and encourage MNR staff to share information between program areas.

The Model project has shown that GIS has tremendous potential to benefit MNR. It can provide more than a technological solution for managing and analyzing geographic data. It can also be a vehicle for organizational change and integration. However, the cost of GIS implementation is a very large capital investment-based on the Model project experience, the cost is approximately $300 per square kilometre. The many observations and conclusions that were developed from the project are invaluable for future GIS implementations. All of these lessons learned and the triumphs made will serve as an important source of information for any future work on GIS in MNR. Therefore, full scale provincial implementation will dictate a cautious, structured and sequenced approach.

THE USE OF GEOGRAPHIC INFORMATION SYSTEMS AT THE U.S. ENVIRONMENTAL PROTECTION AGENCY

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Abstract

Recent advances in computer hardware and software technology have enabled geographic information systems (GIS) to automate the preparation of graphic representations of environmental data. GIS provides the capability to analyze and visualize all of the EPA's data in a geographic context. It has been used extensively in environmental risk assessment, Superfund site cleanup prioritization, Superfund site management, wetlands identification, and water resource management. This paper analyzes the economic impact of GIS to the U.S. Environmental Protection Agency (EPA) in its mission to protect and enhance the environment of our nation. Furthermore, it describes how the Agency proceeded to implement GIS through careful evaluation that included the States. Additionally, the paper highlights specific applications of GIS and benefits realized.

The successful applications of GIS in meeting the Agency's mission goals continue to expand as EPA Regions and Program offices come on-board with this technology.

UTILISATION DE SYSTÈMES D'INFORMATION GÉOGRAPHIQUE À LA U.S. ENVIRONMENTAL PROTECTION AGENCY

RÉSUMÉ

Grâce aux progrès récents dont ont bénéficié le matériel et les logiciels informatiques, les systèmes d'information géographique (SIG) sont aujourd'hui en mesure d'établir de façon automatisée des représentations graphiques de données environnementales. Les SIG permettent d'analyser et de visualiser dans un contexte géographique toutes les données de l'EPA. On s'en est servi abondamment pour l'évaluation des risques environnementaux, l'ordonnancement des travaux de nettoyage des lieux couverts par le Superfund, la gestion de ces lieux, l'identification des terres humides et la gestion des ressources hydriques. Le présent document trace une analyse des répercussions économiques des SIG pour l'EPA dans la poursuite de sa mission visant à protéger et à valoriser l'environnement des États-Unis. On y décrit également les examens attentifs auxquels l'agence s'est adonnée, de concert avec les différents États, aux fins de la mise en place des SIG. Sont finalement exposées des applications précises des SIG de même que les avantages qui en ont découlé.

En cherchant à atteindre les buts de sa mission, l'EPA ne cesse de trouver de nouvelles applications aux SIG à mesure que leur technologie s'implante dans les régions et les bureaux d'administration de l'organisme.

I. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is responsible for implementing the U.S. Federal laws designed to protect the environment. EPA endeavors to accomplish its mission systematically through integration of a variety of research, monitoring, standard-setting, and enforcement activities. As a complement to its other activities, EPA coordinates and supports research and anti-pollution activities of state and local governments, private and public groups, individuals, and educational institutions. EPA monitors the operations of other federal agencies with respect to their impact on the environment. With the growing emphasis on global environmental issues , EPA is also becoming more actively involved in environmental activities with its neighboring countries in North America as well as abroad.

Today, EPA is in the process of institutionalizing the use of Geographic Information Systems (GIS) technology in nearly all aspects of the Agency's mission. This paper will relate how we introduced GIS in EPA and provide examples of GIS applications to illustrate the use and power of this technology in environmental protection. After nearly a decade since GIS was first utilized at EPA, we are now able to document some of the benefits that we are realizing from this technology. However, many of the most significant benefits are not at all what one would expect, or at least, not what EPA expected when we began.

II. GIS AND GEOGRAPHIC INITIATIVES AT EPA

Simply put, GIS is an integrated technology the heart of which is a database management system tailored to handle locational data -- that is, data that can be analyzed and presented in a common spatial framework. A GIS system includes components for the entry, storage, manipulation, analysis, and display or presentation of spatial data. The key purpose of GIS is to place data in a common spatial framework and examine the relationships that become evident only where data are integrated in this way.

In environmental protection, EPA can use GIS to manage and analyze data about water flow and chemistry, soil characteristics, meteorology and demography, etc. and then manipulate and present these data and their relationships. These visual displays have proven invaluable in supporting decision-makers and in discussing pending decisions with the public, legislators, and others who would otherwise either be outside the decision process, or who would participate in the process without a firm grasp of the factors under consideration.

The introduction of GIS technology at EPA has coincided with the development of a new long-term environmental strategy that emphasizes "geographic initiatives". These initiatives focus on areas delineated by distinctive geographic features such as the Great Lakes, the Chesapeake Bay, and the Gulf of Mexico. This new geographic perspective acknowledges the natural interaction between the air, water, and soil in the environment and the influence that natural boundaries have on this interaction. EPA will rely upon the integrating capabilities of GIS to analyze and portray these often complex relationships as it addresses the substantial environmental challenges of today and the future.

III. GIS IMPLEMENTATION IN EPA

The Environmental Protection Agency did not automatically embrace GIS technology, instead a thorough evaluation was performed by two of our Research and Development laboratories located in Corvallis, Oregon and Las Vegas, Nevada. Both groups of scientists were working on complex studies that required analysis of spatial information, including the long-term response of surface water to acidic deposition and the movement of groundwater contaminants through complex subsurface geology. Each group decided quite independently that they needed a special tool to manage these complex data sets and to perform and display the analysis required by policy- makers. In the case of Las Vegas, they were also interested in finding a way to fully utilize remote sensing data in environmental analyses.

In 1983, we assisted both laboratories in acquiring early versions of GIS technology, and watched carefully to see what they were able to accomplish. After about two years, we were convinced of the potential of this new tool and GIS was introduced on an experimental basis in our regional office in Atlanta, Georgia. We wanted to see how GIS could be applied to routine environmental protection work -- permitting facilities, compliance and enforcement work, and managing hazardous waste sites, etc. In the United States, most environmental protection activities, even though authorized or mandated by federal laws, are delegated to and carried out by state governments. So, the State of Georgia's environmental protection agency was invited to participate in the Atlanta regional GIS program. Specifically, a GIS tool was developed to assist State permit writers in evaluating landfill permit applications by identifying suitable sites for landfills.

We learned a great deal from the Atlanta experience about what would be entailed in delivering GIS technology to all parts of EPA. In particular, we learned:

- How to purchase, install, and support GIS computer technology;

- What it costs to acquire and operate a GIS system;

- What is entailed in acquiring and assuring the quality of spatial data of many different types, and where such data can be found in the U.S.

Since the Atlanta pilot, we have installed GIS technology at EPA's Headquarters, in all of our 10 regional offices, and in many of our more than two dozen laboratories. Our full-scale implementation strategy went as follows:

- First, to limit our initial capital investment in what was still a very new and rapidly evolving technology, we installed GIS software on minicomputers that we already owned and that were nearing the end of their useful life in th ir original role of supporting administrative functions. We thought it was far more important to assure the success of this new technology by investing our resources in training and generating useful applications than it was to have the best available hardware. We also recognized that we did not know enough yet to conduct a large-scale procurement that would set the direction of EPA's GIS program for up to a decade into the future. This approach allowed us to complete the installation of GIS in all 10 EPA regional offices within three years.

- Second, before we allowed a region to have a GIS system, we required that they do two things:

  -- The region had to assemble a multi-disciplinary team of up to five (5) people to operate the GIS as a service to the region's programs.

  -- The GIS team had to be placed in a cross-cutting organization within the region, and not in one of the individual line organizations that address only one "media" -- air, water, etc.

- Third, having gained experience in using GIS throughout EPA, and having developed a large body of strong adherents to this technology, we asked for and received the capital to modernize our GIS technology. In this modernization program, we have been able to capitalize on newly-available local and wide-area network technology that allows us to deliver direct access to GIS throughout our professional workforce. We have just completed the purchase of new GIS systems for all EPA regions, and expect this technology to be in all or most EPA laboratories and analytic facilities,and also to our headquarters policy staffs, which up to now have been limited to hard copy products.

EPA's GIS expenditures to date approach 15 million dollars since the technology was first introduced in the mid-1980's. This investment has been primarily focused on the acquisition of GIS technology and associated expertise. EPA has just recently established Agency-wide contracts for the acquisition of GIS software with Environmental Systems Research Institute (ESRI) for their ARC/INFO product and for GIS hardware with Data General. Access to GIS training is also provided through the software contract with ESRI. We expect that the explosive growth of GIS utilization currently being experienced within EPA will undoubtedly lead to increasing expenditures in the future that will be applied in greater portions to spatial data acquisition and management activities.

GIS requires a non-traditional organization -- you cannot simply turn over GIS to the traditional ADP organization where it may not be used effectively, if at all. Computer experts know hardware and software, but they do not know data, and the real costs, problems, and benefits of GIS are tied to data, not technology.

In EPA's case, GIS offered a unique opportunity to change the way people work together. GIS provides a new and extremely powerful way to visualize complex relationships and solve problems in environmental protection, in a way so attractive that people have been willing to surrender organizational primacy in order to gain access to this technology. We have attempted to capitalize on this opportunity by trading technology for organizational reform.

This last point is crucial to understanding the benefits of GIS to EPA. Environmental protection in the U.S. and in most nations has evolved from earlier programs to manage water, land and other natural resources, from public health programs focused on sewage treatment and drinking water supplies, and more recently, from efforts to reduce harmful air pollution. Each of these programs grew up separately and were later combined into something called "environmental protection".

Common sense and science tell us that the environment is, in fact, an integrated whole, and efforts to understand and protect the environment on the basis of separate "media" -- air, water, land, etc. -- are doomed to fail. Unfortunately, environmental protection agencies have had great difficulty in integrating their inherited "single media" traditions and predecessor organizations into a single, coherent, and effective program. Thus, early pollution control often produced pollution transfers -- sludge incineration generates harmful air pollution, "tall stack" air pollution strategies produce acid rain, etc.

In addition to "soft" obstacles such as custom, organizational politics, scientific disciplines, etc., integration of environmental programs and bureaucracies has been blocked by one very concrete obstacle -- the near impossibility of integrating data across the separate media to support holistic environmental assessments and strategies. GIS, in combination with major advances in computing power and data resources, is proving to be a key force in overcoming this obstacle in the U.S. Perhaps the revolution in the information technology world will produce a new offering able to eliminate organizational politics.

IV. GIS APPLICATIONS IN EPA

Before exploring the economic and other benefits produced by GIS, it will help to briefly describe some examples of GIS applications within the EPA.

A. San Gabriel Basin Superfund Site

The San Gabriel basin in southern California includes portions of Orange County and the City of Los Angeles and its aquifer provides drinking water to an estimated 1.2 million people. In 1984, the 170 square mile (440 square kilometer) basin was placed on the EPA's National Priorities List (NPL) due to extensive ground water contamination from four hazardous waste sites. In 1985, the EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV) implemented the Agency's first Superfund site GIS application at the request of the Region 9 Superfund program. (Superfund is the United States' mechanism for identifying and remediating abandoned hazardous waste sites which have significant public health implications.)

The San Gabriel Basin investigation focused upon the evaluation of contamination extent, prevention of exposure to contaminated groundwater, and development of a basin-wide remediation strategy. GIS was used throughout the remedial investigation/feasibility study to effectively manage, analyze, and query the vast amount of spatially referenced data that were used to characterize the site. There are approximately 1,500 wells at the four San Gabriel sites where monitoring of volatile organic compounds (VOC) still occurs. The application included the analysis and display of three-dimensional groundwater monitoring information, e.g., well log data interpolated as contaminant plumes. These plumes were used to identify changes in contamination movement in relation to groundwater flow patterns, temporal changes in groundwater quality and contaminant migration, water management scenarios (pumping impacts), and sources of contamination. Utilizing this information, the remediation plan at San Gabriel calls for managing groundwater withdrawals in order to slow, and eventually reverse, the spread of contamination.

The findings of a GIS cost/benefit analysis performed on this application has documented significant cost savings and both tangible and intangible benefits from using a GIS when compared to traditional cartographic and computer aided design (CAD) based methods. Perhaps the most dramatic cost savings was reflected in terms of the reduction in labor hours required when a GIS was used for analyzing and mapping the contaminated groundwater plumes from data gathered at the 1,500 monitoring wells. This represents a 9-fold decrease in the labor-hours required to analyze and plot the well data, interpolate the plume boundaries, and prepare the maps.

In addition to improvements in the remediation planning process, numerous other benefits of GIS were realized during the project:

- GIS maintained a central, convenient access point for all the data necessary for plume analysis, greatly facilitating routine access, including all historical data;

- GIS allowed rapid selection and subsetting of the data for analysis and mapping;

- GIS facilitated the use of very sophisticated groundwater flow models, and much of the analysis would not have been completed in a timely manner if they were required to do the same work by hand;

- Because some of the base data for the project, including census demographic data and the road networks used to accurately locate many of the monitoring wells, was available digitally, GIS actually facilitated the production and acquisition of new data that would have been required regardless of the method of analysis and integration; and

- The scientists on the project emphasized that the enhanced communication of their scientific results to the public was a primary benefit of the GIS technology.

The economic impact of GIS on this project continues today. Because all of the data was collected and stored in digital format, that data is now available for use by other agencies. And, in fact, the regional water authorities are using the GIS database for natural resource and human health risk assessments. EPA has implemented a new recycling program -- not paper or plastic or used oil, but data.

B. Shaver's Farm, Georgia

Shaver's Farm is located in central Georgia, USA. In the early 1970's portions of this land were leased to chemical companies, where they buried hundreds of barrels of toxic chemicals at the site. The companies concealed their activities, and no one knew for certain what they were disposing. In 1987 a report came to EPA that possible uncontrolled hazardous waste disposal had been occurring, and a groundwater monitoring assessment revealed the presence of a toxic herbicide.

Following a round of legal paperwork with the chemical companies believed to be responsible for the contamination, EPA was not satisfied with the answers, although the companies' legal obligations had been fulfilled. Consequently, EPA performed a geophysical assessment of the site with three different surface-based sensors: electron magnetometer, proton magnetometer, and WADI -- a low-frequency radio-wave detection device.

This is where GIS demonstrated its unique value. Taking the point measurements from the three devices, GIS produced contours which showed the anomalies each device detected. GIS then allowed the rapid overlaying of this data for a visual merging for presentation. Within two weeks of the time the field crew delivered its data from the geophysical recorders, the GIS analyst had delivered an initial assessment to the site manager. This information allowed the site manager to instruct the GIS team about how best to represent the data.

The results? Because of data which was collected with highly accurate spatial coordination, digging at several sites identified by the geophysical sensors has unearthed over 1,200 barrels. This procedure has resulted in a 100% predictive accuracy rate with the GIS providing a very rapid turnaround on data analysis, interpretation, and display. As with the San Gabriel site, manual methods would have required several additional weeks' worth of work, and each additional combination of the data from the three recorders would have added an equal amount of recalculation and redrawing time. Here we find GIS, coupled with other advanced technologies, combining and enhancing their capabilities to make a real breakthrough in the remediation of a life-threatening abandoned toxic waste dump.

C. Denver - Rocky Mountain Arsenal Area Cancer Study

The Rocky Mountain Arsenal is a large area near Denver, Colorado owned by the U.S. Army which has been publicly criticized over the past few years because of the release of toxic chemicals into the environment from the site. Recent studies of the incidence of cancer in the area have revealed higher than normal rates of certain types of cancer. Immediately, people jumped to the conclusion that the arsenal was responsible and demanded retribution from the government for injury. But the ability of GIS to integrate data from various isolated sources suggests that this is not necessarily the case. When the areas around the arsenal were divided into three zones, and other sources of data were applied, a rather surprising relationship was revealed. While two of the surrounding zones had cancer rates that fell within the bounds of what would be expected, the one zone which displayed the higher rates or incidences of cancer also had a preponderance of hazardous waste sources in the immediate area. This spatial relationship suggests that the arsenal may in fact not be the causal link with the increased cancer rates that everyone assumes.

This is a case where GIS' ability to integrate information from diverse data sets provides the potentially monumental economic benefit of precluding the success of a class-action lawsuit for damages against the U.S. Government. However, of greater importance is the ability to evaluate the potential impacts of those identified hazardous waste sources in an effort to reduce the potential human health risks to the surrounding population. It will be difficult to assess the total impact, but we can state conclusively that the analysis which revealed these relationships probably would not have been undertaken without the abilities afforded by GIS. It should be noted that the EPA Region 8 GIS team performed this analysis and displayed the results within a 24-hour turnaround, assisting the epidemiologists who were preparing to release their findings to the public.

D. Oregon Clean Water Strategy

The Oregon Clean Water Strategy (CWS) GIS provided the State of Oregon environmental managers with a capability to dynamically compare, contrast, and ultimately prioritize water management activities and resource allocation decisions cross-programmatically. The Oregon CWS GIS explicitly relates known pollution impacts to a publicly determined value system for waters, such as drinking water, fishing, swimming, fish spawning areas, etc., on a geographically-specific (i.e., stream-by-stream) basis. The unique benefits of this GIS approach to setting water management priorities are threefold.

First, Oregon was able to prepare comprehensive maps and lists of all State streams and waterbodies in order of management priority based on a selected ranking method. Second, Oregon officials were able to use these lists to communicate their priorities to many other federal, state, and regional organizations, and to develop a cross-organizational consensus on where common problems existed. Finally, Oregon was able to use the Oregon CWS GIS and its outputs to develop geographically-specific agreements with "sister" agencies to jointly manage the affected resources and coordinate clean-up strategies. The Oregon CWS GIS was effective because of its powerful data integration and communication capabilities; the latter translating sophisticated analysis into intuitive and credible information.

E. Chesapeake Bay Restoration

The 1987 Chesapeake Bay Agreement mandates the restoration of submerged aquatic vegetation (SAV). This important group of plants creates a minor ecosystem which is the predominant source of shelter and food for the young of many varieties of ecologically and commercially important species, including oysters, bluefish, and rock bass. These species use the shallow, brackish waters of the Bay as a nursery for young fish which are often spawned in the freshwater tributaries of the Bay, and which sometimes migrate into the ocean. The massive, prolonged loss of submerged aquatic vegetation was the single most dramatic indicator of the precarious state of the Bay's overall health.

The Chesapeake Bay Program is using GIS technology to identify specific areas which have substantial submerged aquatic vegetation and additional areas of potential SAV habitat. Defining the specific geographic areas where SAV is currently growing and where it may be expected to grow, provides an unambiguous target against which progress can be measured. Potential habitat is defined as those areas with depths of two meters or less with suitable substrate for SAV growth.

Using GIS, the Chesapeake Bay Program has been able to more effectively gauge whether the Bay's SAV resources are increasing or decreasing as it strives to meet its restoration goals.

V. ECONOMIC AND OTHER BENEFITS OF GIS TO EPA

The true benefits of information technology are typically found in doing things that would otherwise be impossible, not from performing current tasks more efficiently. This is the lesson of the past 20-30 years of experience in applying information technology to all fields except perhaps the most routine, labor intensive functions such as those found in insurance companies and banks.

Yet, we will still gladly cite numerous examples of how GIS helps EPA do its work more effectively, and in doing so, reduce the ultimate cost of performing the work at hand. GIS has helped measurably in our efforts to communicate with the public, and as a result, gain acceptance for essential measures to protect human health and natural resources. Since we often cannot act until we obtain public consent, GIS helps reduce the endless debates and delays that can afflict the decision-making process in a democratic society. We also have a growing body of examples of GIS helping us perform critical management functions, such as integrating field samples from several different contract teams working on different phases of a single hazardous waste site clean-up, thereby helping us to obtain value for the fees we pay and avoid unnecessary work. There is also strong evidence that, applied in this way, GIS is shortening the process of cleaning up hazardous waste sites, and if that is true, the savings are enormous.

The real benefits of GIS, however, come in forms that are very difficult to measure. These benefits are the result of being able to think and do things that are impossible to imagine without the spatial integration and visualization made possible by GIS. Nonetheless, economic and other equally important benefits can be imputed, as shown by the following examples:

- We estimate that EPA expenditures for environmental monitoring now exceed $500 million annually. Unfortunately, much of the monitoring data have been essentially inaccessible to anyone other than the initial gatherer/user. GIS is changing that, and in the process, yielding enormous improvements in data quality, which inevitably improves when data are used rather than merely gathered and stored. The total "life-cycle" cost of EPA's investment in GIS is about $38 million, or less than 7% of one year's spending on monitoring. It will not require much in the way of improved data or use of data for GIS to produce a favorable benefit/cost ratio.

- EPA programs are evolving into integrated, multi-media efforts keyed to environmental results, rather than intermediate, and often misleading, measures such as the reduction of emissions without regard for cost or ultimate environmental benefit. GIS has been an important factor in bringing about this shift, by providing the analytic underpinning for program integration and by leading/forcing changes in organization and policy. There is a growing body of evidence that an integrated approach to environmental protection does avoid billions of dollars in costs to the U.S. economy and yields far superior protection of human health and natural resources.

- EPA is moving to a long-term strategy that emphasizes "geographic initiatives" and organizes around major geographic features, such as the Great Lakes and the Chesapeake Bay. This strategy is based on the belief that "people protect that which they love". People do love the Great Lakes and similar geographic features that dominate their economic, cultural, and social lives. To protect these resources, people will take actions voluntarily that are beyond the reach of legal coercion. How much is that worth?

- GIS has opened the door to vast amounts of data that had been inaccessible to EPA for practical reasons -- we simply lacked the means to use these vast data bases in any practical way. Examples include soils and geological data and land use information. Although EPA is understandably pleased by integration within our own data and programs, the benefits of integration with data and programs outside EPA may prove to have far greater benefits.

For example, EPA is currently designing a program to address the environmental hazards faced by the poor, often minority residents of our inner cities in response to evidence that these citizens are disproportionately affected by pollution. GIS, combined with the U.S. Census Bureau's move to provide demographic data in a GIS format, now permits us to achieve a much finer resolution in assessing health effects of pollution on specific populations. It will now be possible, for the first time, to address the issue of "environmental equity" for our vulnerable citizens.

- GIS allows us to intervene to protect the environment in ways that would seldom have even been considered in the past. To illustrate, state environmental agencies have used GIS technology to influence transportation and land use planning, an area with great impact on long-term environmental trends, but previously beyond the effective reach of case-by-case regulation.

- EPA is now implementing a nationwide Ecological Monitoring and Assessment Program (EMAP) that would be impractical without GIS as its basic data management strategy. This program promises to provide the first statistically reliable information about the status and trends of ecosystems, and insight into the conditions that are affecting their overall health. Initial results suggest that this program will allow us to better target programs to mitigate the effects of pollution on ecosystems, and by doing so, avoid broad- brush regulatory strategies that impose enormous costs on American industry.

VI. CONCLUSIONS

While we believe the potential for GIS to strengthen environmental protection in the long-term is enormous, the application of GIS technology to environmental protection presently offers only very modest, near term cost savings. However, GIS technology appears to offer very large-scale, long-term economic and policy benefits by enabling new program strategies; by permitting the use of previously inaccessible and enormously valuable data; by supporting new, more valid monitoring methods; and by driving fundamental changes in traditional institutional roles and structure. In view of this, the strategy for implementing GIS in an environmental protection agency or ministry should be designed to both foster and capitalize on these long-term changes.

EPA's mission is clearly geographic in nature. Geography will serve as the common integrating factor that enables us to combine environmental and natural resource data in ways that will allow us to more effectively protect the environment. Substantial benefits of applying GIS to solving environmental problems are already being realized throughout the EPA and its use will most certainly play a critical role in meeting the increasingly complex environmental challenges of the future.

PROGERT
RESEARCH AND DEVELOPMENT PROJECT
FORESTRY REMOTE SENSING AND GEOMATICS

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Abstract

During the last years, major developments took place in remote sensing and geographic information systems (GIS). Increasing quantity and quality of satellite and airborne data, combining with digital processing techniques, are opening new avenues in geomatics and remote sensing. On the other hand, lack of homogeneous utilisation prevents coherent and eficient application of these data and technologies. Confronting this innovative and rapidly evolving situation, eight industrial promoors have created a consortium grouping service companies, universities and users with the scope of opening new possibilities in remote sensing and geomatics oriented to natural ressources management, particularly in forestry.

PROGERT
PROJET MOBILISATEUR DE RECHERCHE ET DÉVELOPPEMENT
TÉLÉDÉTECTION ET GÉOMATIQUE EN FORESTERIE

Résumé

Au cours des dernières années, les domaine de la télédétection et des systèmes d'information géographique (SIG) ont bénéficié de développements importants. La quantité et la qualité des données satellitaires ou aéroportées augmentent sans cesse alors que l'univers des méthodes numériques ouvre des possibilités jusqu'alors insoupçonnées en télédétection et en géomatique. Cependant, il existe une absence d'homogénéité entre les intervenants afin d'exploiter de façon cohérente et efficace toutes ces technologies. Faisant ainsi face à ce contexte d'évolution rapide et d'innovation, huit promoteurs industriels ont mis sur pied un consortium regroupant des entreprises, des universités et des utilisateurs afin de relever un défi technologique permettant d'envisager de nouvelles possibilités de télédétection et de géomatique reliées à la gestion des ressources naturelles, particulièrement la forêt.

Au cours des dernières années, les domaine de la télédétection et des systèmes d'information géographique (SIG) ont bénéficié de développements importants au niveau de leur technologie respective. La quantité et la qualité des données satellitaires ou aéroportées augmentent sans cesse, l'univers des méthodes numériques ouvre des possibilités jusqu'alors insoupçonnées alors que les équipements, les logiciels et la recherche en télédétection et en géomatique progresse rapidement. Cependant, il existe une absence d'homogénéité entre les intervenants afin d'exploiter de façon cohérente et efficace toutes ces technologies. Faisant ainsi face à ce contexte d'évolution rapide et d'innovation, huit promoteurs industriels ont mis sur pied un consortium regroupant des entreprises, des universités et des utilisateurs afin de relever un défi technologique permettant d'envisager de nouvelles possibilités de télédétection et de géomatique reliées à la gestion des ressources naturelles, particulièrement la forêt pour les gouvernements et les industries concernés.

Projet de Recherche pour l'Observation et la GEstion des Ressources Terrestres, PROGERT a comme objectif général de développer au Québec une industrie de calibre international dans les domaines de la télédétection intégrée aux systèmes d'information géographique par le développement d'outils et de méthodes qui permettront une gestion forestière plus efficace et moins coûteuse (voir figures 1 et 2). PROGERT, qui est encouragé en partie par l'apport financier du Fonds de développement technologique (FDT) du Gouvernement du Québec représente un investissement de l'ordre de 28 M$ et des efforts de plus de 2000 personnes-mois provenant des 8 promoteurs de ce projet échelonné sur 5 ans. L'équipe de promoteurs est composée des industriels suivants: BCGT Inc., Haut-Monts Inc., Ibm Canada Ltée, Innotech Aviation Enterprises Ltd, Poulin Thériault Inc., SNC Inc., SPAR Aérospatiale Limitée et Tektrend International Inc. En participant à PROGERT, chaque intervenant s'engage à pousser plus loin sa recherche, à améliorer les produits existants et en mettre au point de nouveaux afin de répondre aux besoins des utilisateurs.

Pour réaliser PROGERT, le choix de l'application s'est arrêté vers le secteur forestier qui, de part son caractère dynamique et ses exploitations multiples, fournit un milieu idéal et fort représentatif pour le développement et l'exploitation de la télédétection et des SIG. De plus, des intervenants aux intérêts complémentaires ont été choisis pour leur expertise dans différents secteurs stratégiques de l'industrie. Ces intervenants sont regroupés en 3 catégories; les **utilisateurs** représentés par les industries forestières et les organismes gouvernementaux responsables de la gestion et de l'utilisation des forêts, les chercheurs **universitaires** et les institutions de recherche qui fournissent la base scientifique et assurent l'avancement de la technologie et les promoteurs **industriels**, spécialisés en télédétection et en SIG, intéressés à développer le secteur et à mettre à profit les résultats (voir figure 3).

L'idée de base de PROGERT est de recueillir des données concernant le territoire à l'aide de capteurs aéroportés, satellitaires et de relevés de terrain, d'analyser, de traiter et d'interpréter ces données pour finalement les intégrer dans un système d'information géographique afin de développer des outils adaptés à la gestion forestière (voir figure 4). Pour faciliter l'organisation et la gestion du projet et permettre des regroupements par secteur entre des intervenants aux intérêts communs, PROGERT est subdivisé en 4 projets distincts; un projet de support technique et d'intégration ainsi que trois projets de recherche et développement (voir figure 5).

Projet 1: **Support technique et intégration.** Ce projet, qui orientera de façon significative les 3 projets de recherche, assure une plus grande efficacité d'exécution de PROGERT en regroupant les besoins communs et en coordonnant l'ensemble des

activités afin d'atteindre l'objectif général du projet. Les activités de ce projet sont coordonnées par SNC Inc. et regroupent tous les intervenants.

Projet 2: **Système d'acquisition de données.** Ce projet examine la technologie et les performances des systèmes complets de prise de données afin d'identifier les plus aptes à servir les besoins de la gestion forestière. Les activités du projet 2 sont coordonnées principalement par les industriels Innotech Aviation Entreprises LTD et SPAR Aérospatial Limitée;

Projet 3: **Traitement, analyse et interprétation des images.** Ce projet concerne la recherche et le développement reliés au traitement, à l'analyse et à l'interprétation des données brutes produites par les capteurs jusqu'à l'extraction de l'information utile de ces images.Le projet 3 est coordonné principalement par Haut-Monts Inc.;

Projet 4: **Système d'information à référence spatiale.** Le succès de PROGERT se traduira finalement par l'intégration des données, acquises et traitées dans les projets 2 et 3, dans un modèle de système d'information à référence spatiale incorporant les différents éléments nécessaires à la gestion des ressources forestières. Les différentes activités sont coordonnées par BCGT Inc., IBM Canada et SNC Inc.

BCGT a le mandat de coordonner conjoitement avec IBM et SNC les activités qui contribueront directement ou indirectement au succès du projet 4 "Système d'information géographique". Doté d'un budget de plus de 10 M$, ce projet se situe au coeur même de PROGERT car il intègre les données et les résultats issues des projets 2 et 3 dans un système d'information géographique. Parallèlement à cette coordination de projet de développement du SIG, BCGT participe à 2 sous-projets du projet 4, soient:

- développement d'un prototype de SIRS,
- définition des exigences techniques des SIRS selon les besoins des utilisateurs.

De plus, BCGT Inc. est responsable de la réalisation du sous-projet concernant le développement d'un prototype de SIRS. Ce sous-projet vise à concevoir, développer et mettre à l'essai un prototype de SIRS permettant d'intégrer l'ensemble des données nécessaires à une gestion moderne de la forêt, incluant particulièrement celles provenant des projets précédents de télédétection, ainsi que d'exploiter automatiquement ces données avec les traitements appropriés. De plus, ce sous-projet répond à la fois aux nouveaux besoins de réalisation pratique pour la gestion intégrée des ressources forestières ainsi qu'au développement et la mise en valeur de l'expertise québécoise en géomatique forestière. Afin de réaliser le prototype de SIRS, différentes activités ont été définies, soient:

- **Analyse des SIRS existants** présentement utilisés au niveau de l'industrie forestière et du gouvernement afin d'établir les différentes manipulations effectuées sur les données et les traitements désirés.

- **Développement d'un modèle conceptuel de données** qui constitue le noyau de tout système et qui permettra de gérer autant l'aspect évolutif de la forêt que son aspect spatial et la nature des données stockés.

- **Développement d'un modèle des traitements** afin de bien situer les activités et les opérations que les utilisateurs désirent effectuer sur l'ensemble des données afin

de bien gérer la ressource forestière.

- **Développement d'un modèle logique de données** qui permet de faire la transition entre le conceptuel et la technologie retenue.

- **Développement du système** qui consiste à programmer chacun des modules identifiés au niveau du modèle des traitements. Le développement sera effectué en tenant compte des différents logiciels et plate-formes technologiques existants sur le marché.

- **Documentation du système** qui comprend celle du logiciel et des modèles de données et de traitements.

En participant à PROGERT à plusieurs niveaux (voir figure 6), BCGT voit ainsi l'occasion d'accroître son expertise dans les domaines de la géomatique et de la gestion de projet afin de se maintenir compétitif au niveau du marché. L'apport des autres intervenants et des universitaires contribuera également, de part leur connaissance, leur expérience, leur technologie et leur méthode de travail, à améliorer la qualité de l'équipe de spécialiste de BCGT. De plus, BCGT ne peut que bénéficier de l'objectif principal de PROGERT qui vise le développement d'une industrie de calibre international pour la commercialisation des produits et des services qui seront issus du projet. Finalement, BCGT sera apte à viser les domaines tels: l'agriculture, la géologie, l'hydrologie et l'environnement car les produits commercialisables seront développer de façon à être facilement adaptables à d'autres disciplines.

Définition

Projet de
Recherche pour l'
Observation et la
GEstion des
Ressources
Terrestres

Projet mobilisateur de recherche et développement visant les technologies d'acquisition, d'analyse, de traitement et d'interprétation des données de télédétection pour des applications thématiques dans des domaines d'intérêt socio-économique telle la forêt.

figure 1

Objectifs globaux

- Concevoir et développer des applications de **la télédétection intégrée aux systèmes d'information à référence spatiale (SIRS)**
- Elaborer des concepts et méthodes et mettre au point des outils pour supporter la mise en place de ces applications
- Instaurer une infrastructure industrielle québécoise de calibre international en vue d'accélérer la commercialisation des produits et services issus de PROGERT
- Favoriser l'utilisation de technologies de base existantes au niveau des logiciels de télédétection et de SIRS

figure 2

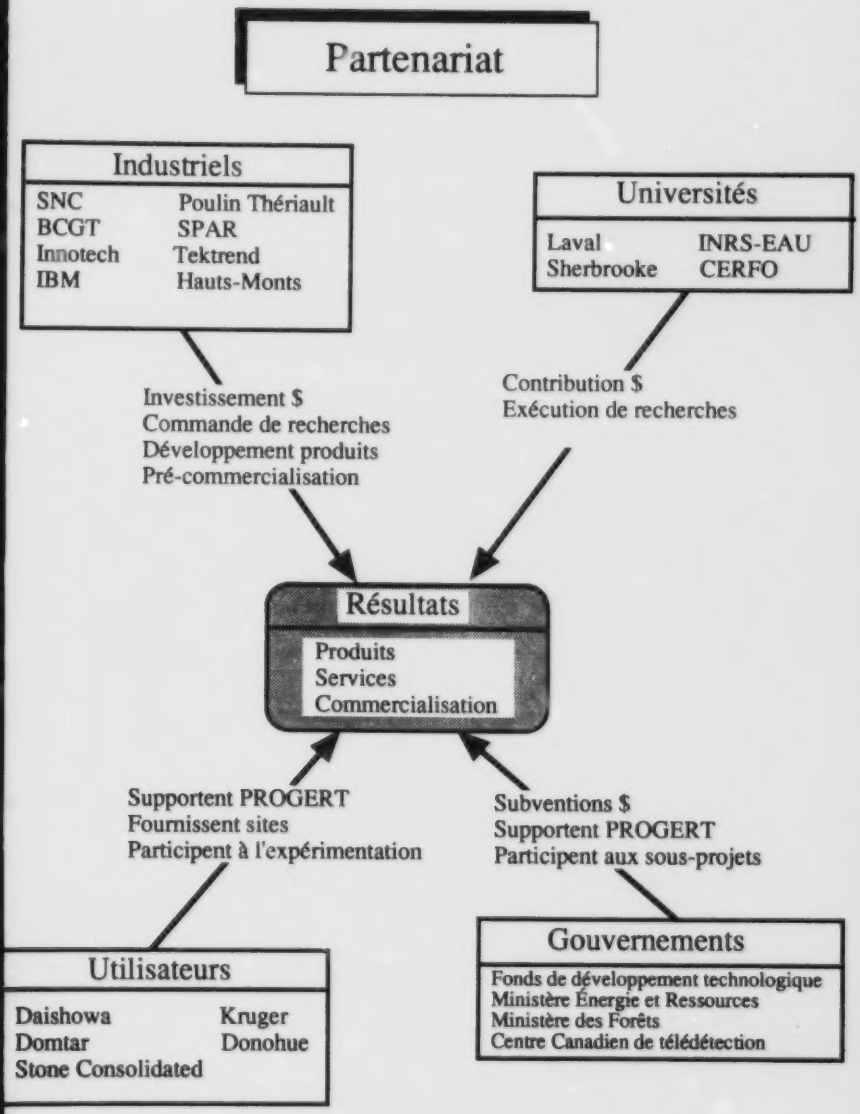
Partenariat
Industriels
SNC
Poulin Thériault
BCGT
SPAR
Innotech
Tektrend
IBM
Hauts-Monts
Universités
Laval
INRS-EAU
Sherbrooke
CERFO
Investissement $
Commande de recherches
Développement produits
Pré-commercialisation
Contribution $
Exécution de recherches
Résultats
Produits
Services
Commercialisation
Supportent PROGERT
Fournissent sites
Participent à l'expérimentation
Subventions $
Supportent PROGERT
Participent aux sous-projets
Utilisateurs
Daishowa
Kruger
Domtar
Donohue
Stone Consolidated
Gouvernements
Fonds de développement technologique
Ministère Énergie et Ressources
Ministère des Forêts
Centre Canadien de télédétection

figure 3

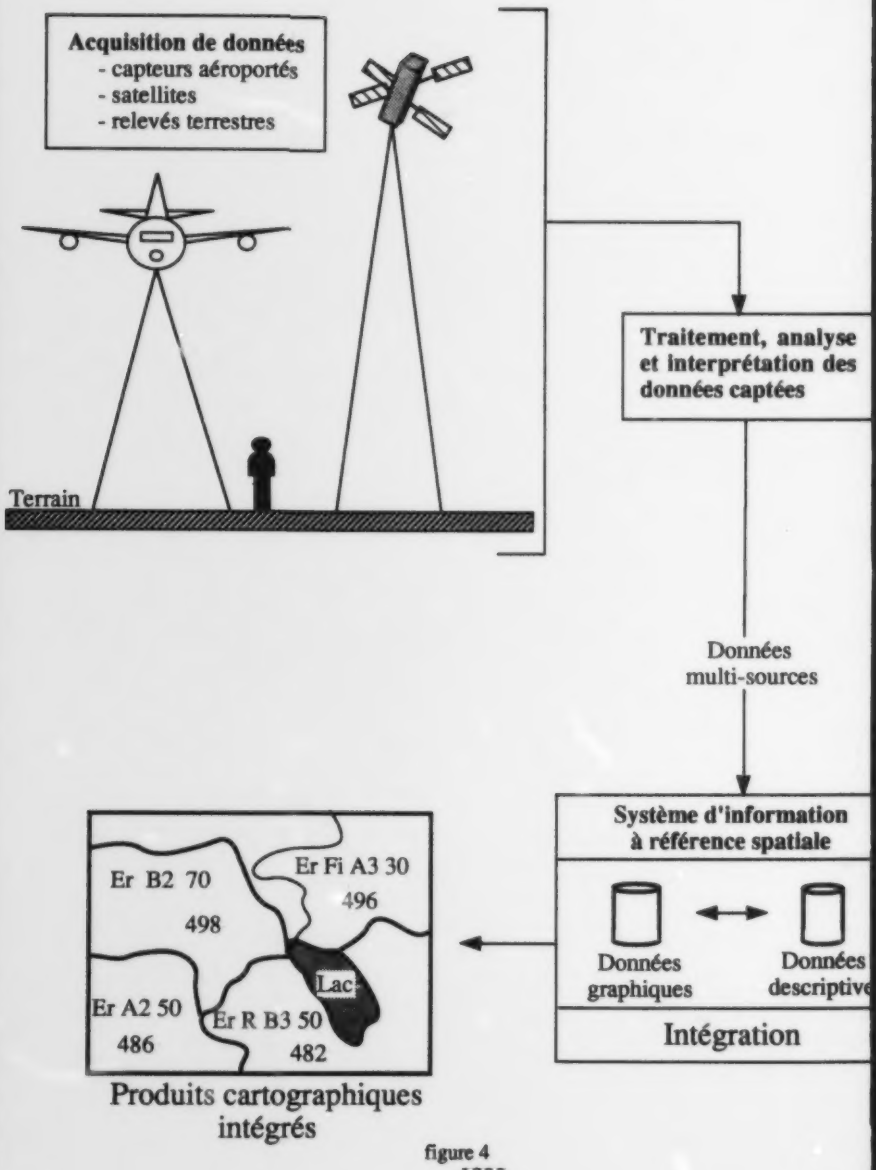

figure 4

1000

Identification des sous-projets

Projet 1 - Support technique et intégration

11 - Analyse des besoins et techniques existantes en télédétection et géomatique.
12 - Normes
13 - Études de marchés
14 - Cueillette de données d'expérimentation
15 - Démonstrations
16 - Formation
17 - Précommercialisation des produits
18 - Retombées socio-économiques de PROGERT
19 - Liaison avec les programmes extérieurs

Projet 2 - Systèmes d'acquisition de données

20 - Définition des exigences techniques des capteurs
21 - Analyse, développement et opération du capteur MEIS FM
22 - Analyse, conception et développement de capteurs spécialisés
23 - Développement d'une station d'étalonnage
24 - Développement d'une dtation de réception locale
25 - Correction d'images VIR

Projet 3 - Traitement, analyse et interprétation des images

30 - Correction d'images Radar
32 - Études comparatives d'images ROS
33 - Développement de modèle de texture
34 - Développement des méthodes d'accentuation d'images
35 - Développement 3 D
36 - Développement des méthodes d'analyse (segmentation)
37 - Développement des méthodes d'analyse (classification)
38 - Système expert de formation en interprétation d'images
39 - Interprétation automatisée d'images
40 - Mise au point d'une plate-forme informatique

Projet 4 - Système d'information à référence spatiale

50 - Définition des exigences techniques des SIRS
53 - Apports technologique et support informatique
54 - Conception d'un outil de prototypage rapide
55 - Systèmes d'acquisition et de numérisation
56 - Systèmes de sorties (cartes et rapports)
57 - Développement d'un prototype de SIRS
60 - Fourniture d'équipement pour la plate-forme informatique

figure 5

Participation de BCGT

- **Coordonnateur:**

  Projet 4: Système d'information à référence spatiale

- **Responsable:**

  Projet 4
  - Sous-projet # 57 Développement d'un prototype de SIRS

- **Participant:**

  Projet 1
  - Analyse des besoins des utilisateurs
  - Analyse des techniques existantes en télédétection et en géomatique
  - Etablissement des normes et standards de développement
  - Diffusion des résultats
  - Formation

  Projet 4
  - Définition des exigences techniques des SIRS
  - Développement d'un prototype de SIRS-Forêt

figure 6

THE CITY OF EDMONTON

GEOGRAPHIC BASE INFORMATION SYSTEM

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Abstract

The City of Edmonton has been implementing a multi-participant GIS project since 1978. The project currently involves the participation of eleven civic departments and two private utilities with over sixty organizational units using GBIS to meet operational needs. This paper provides a brief background of the GBIS Project and provides an overview of the strategic direction that is seen for the 1990's based on experience gained during the past 12 years.

SYSTÈME D'INFORMATION GÉOGRAPHIQUE DE BASE DE LA VILLE D'EDMONTON

RÉSUMÉ

La ville d'Edmonton travaille depuis 1978 à la mise en place d'un projet de SIG auquel participent actuellement 11 services municipaux, 2 entreprises privées de services publics et plus de 60 unités organisationnelles qui ont besoin du SIGB pour répondre aux nécessités de leurs services. Dans cet article, l'auteur expose brièvement l'historique du projet; il donne ensuite un aperçu de l'orientation stratégique qui devrait être adoptée dans les années 1990 compte tenu de l'expérience des douze dernières années.

1. INTRODUCTION

During the 1970's, the City of Edmonton was dealing with a number of significant but unrelated factors which affected land related mapping activities. Most significant of these factors included:

- The City was experiencing unprecedented growth.
- The Province of Alberta initiated a program to produce precise cadastral maps based on surveyed coordinates.
- The Federal Government adopted metric measurement standards.
- With the exception of the privately owned natural gas utility and cable television, the City of Edmonton owned its utilities.
- Automated mapping and graphics technology was reaching the stage where broad based application was possible.

This combination of unrelated circumstances not only provided the justification for implementing an automated mapping system, but also provided the mechanism for initiating one of the most comprehensive land based information systems in North America.

The need for an integrated and uniform approach to collecting and storing land information was recognized by the Government of the Province of Alberta, and an urban surveying and mapping program was commenced in the 1960's. The objectives of the program were to establish a rigid geodetic survey network, to relate the existing and future individual land units to it, and to produce map sheets at scales of 1:1000 and 1:5000 as a basis for collecting and storing related land information in a coordinate reference system.

Taking advantage of this direction, the City of Edmonton initiated a Geographic Base Information System Project in 1978 after two years of review. One of the major thrusts of the project was to utilize a single, accurate base for recording all utility infrastructure data in a joint initiative.

2. HISTORY

Starting Up (1978 - 1982)

This phase could be classed as "The Honeymoon" period. The first hardware was received in early 1978 and a Project Team and series of committees was established to guide and implement the Project. Project implementation was designed to meet the following objectives:

- To reduce the costs of metricating City maps and plans.
- To increase drafting productivity.
- To provide user departments with uniform, high quality, accurate maps.
- To facilitate the integration of land and property based information and allow for development of decision support functions such as operations management, land use planning and

analysis. This also included the development of common utility maps in support of construction planning, utility searches and emergency planning.

Implementation priorities were established as:

1. Cadastral Base Map.
2. Utility Cadastre.
3. Department specific graphics.
4. Department specific non-graphics.

One of the major integrated undertakings was the agreement by all participants as to the form and content of the utility cadastre. This involved developing information requirements, level structures, symbologies and input procedures to insure the needs of all users were met for utility searches.

By 1982, most major agreements and understandings were in place. However, the Project took on a different look when a corporate organizational change which lowered the Project team profile combined with high outside demand, resulted in four key members of the project team leaving.

Growth Pains (1982 - 1984)

With the departure of key people, the Project was reorganized in 1982 with base mapping responsibilities transferred to the Engineering Department (now Public Works Department), the remaining Project staff assigned to the Computing Resources Department to perform Project support, and overall Project management and coordination assigned to a series of committees. The committee structure involved five committees in a hierarchical format, two senior management, one mid-management/senior technical and two working level.

Although significant progress was being made in the mapping area, this structure had difficulty effectively dealing with many of the issues. As a result, a complete review of the GBIS Project was undertaken by the City's Corporate Studies Office in 1984.

The study identified seven strategic issues, three organizational issues, two financial issues and four technical issues. Upon analyzing the issues, the report made three significant observations:

- Most of the issues were symptomatic of the fact that GBIS is an expensive, complex, interdepartmental project being implemented over a time period in excess of 10 years.
- The majority of issues were oganizational, not technical.
- The Project was approaching a critical stage of development and required a re-evaluation and re-definition of direction.

As a result of the review, senior City management approved three recommendations:

1. That a full-time project manager be appointed.

2. That the City reconsolidate its present position and departments re-justify their involvement.

3. That the City re-affirm GBIS as a corporate system and maximize its potential.

A New Focus/Reconsolidation (1985 - 1987)

A GBIS Project Manager was appointed in December, 1984. In March, 1985, an action report was approved which included revised mandate, goals, management principles and organization, as well as a series of seven objectives to address the issues raised in the 1984 review.

Since this phase focused primarily on reconsolidation, the major effort was in getting the system into a position where it would not only be more effective for existing users, but also be able to expand and support new users and applications. Some of the significant steps achieved during this phase included:

- A hardware upgrade plan was approved and implemented to replace outdated equipment.
- "Project Champions" in user departments have new life and the Project has a focal point for concerns, problems, and information.
- There is a clear understanding of responsibilities and direction.
- New agreements were negotiated with N.U.L. for data and cost sharing and with the Provincial Government for base mapping.
- A concept of central storage of common (corporate) data was implemented.

Rapid/Expansion (1987 - 1990)

1987 was another transition year for the GBIS Project. The majority of the hardware upgrades were completed, the coverage of the City reached a useable point, lower cost compatible technology became available and most of the reconsolidation type objectives had been addressed. This provided a basis for the emphasis to shift to the objective of "enhancing the system for a broader range of decision making activities and expanding the utilization of the system" while ensuring that the base objectives were not lost.

As more people began to understand the potential of GBIS and the coverage of the city reached a useable level, the number of users increased from 9 user groups or organization/units in 1985 to over 40 in 1990. This rapid growth resulted in a new series of challenges for project management. Some of these challenges included:

- The committee structures which were downsized in 1985 were no longer meeting the needs.

- Growth was occurring in new, isolated areas where there was no peer, or direct support for training and day-to-day assistance.
- Demand was increasing from outside agencies for access to the City's data.
- The City began a process to replace its mainframe computers and re-engineer many of its business systems.
- Demand was increasing for access to non-graphic data which traditionally had been accessed only by the "owner" department.
- The City underwent a series of organizational changes.

The Next Phase (1990 +)

GBIS reached a major milestone in 1990 by celebrating the completion of the base mapping, utility mapping, parcel mapping, single line street network, as well as enhanced ability to link graphic and non-graphic data. The user groups have access to GBIS data with VAX based systems, PC's, Mac's, and Unix workstations. Data is stored on file servers, mini computers and locally. The graphics network has not yet been connected to the business networks which involve independent VAX, HP, IBM, and Unisys computers. Given the number of changes and challenges occurring, as well as the wide variety of departmental and corporate applications being developed, a strategy for the 1990's was presented to City Council in August 1990.

3. THE GBIS STRATEGY FOR THE NINETIES

This "Strategy for the 1990's" outlined what can be expected in developments related to GBIS over the next 5-10 years. It also outlines the growth strategies, the partnerships, management strategies and the project organization structure necessary to ensure continued success.

GBIS Project Mandate

"To develop and maintain a cost-effective corporate system of policies, procedures, organization, hardware and software that is centered around computer graphics technology, which:

- Facilitates the integration of graphic and non-graphic land and property-based data to provide accurate, timely and relevant information in support of City operations.
- Provides users with uniform, high quality, accurate maps and plans.
- Provides access to geographical information, both internally and externally.
- Ensures that information obtained is accurate, consistent and current.
- Ensures that individual privacy and confidentiality are protected.

- Provides support and assistance to private industry and other municipalities on a fee for service basis."

GBIS Project Goals

1. To be able to access, at one time and at one terminal, all information held by the City related to a specific location (property) or area or group of properties to meet operational or emergency response needs.

2. To provide public access to all geographically related public information through a single terminal (location).

3. To be assured that the information obtained through goals 1 and 2 (above) is current, accurate and consistent.

4. To represent the physical environment of Edmonton through GBIS (i.e., to provide a "picture" of any location in Edmonton that very closely represents the real world).

5. To foster local economic development by providing assistance and support to Edmonton and Alberta business in their endeavour to secure contracts outside of Edmonton.

Project Management Approach

The GBIS is guided by the following management principles:

- GBIS must address the needs of the primary service elements of the corporation.
- GBIS must embrace the mission statement of the corporation.
- The Project team will use departmental staff on task forces.
- Committee creation will be minimized by employing a "user group" concept.
- Designated "experts" in user departments must provide assistance to other users in the same area.
- Management must commit to adequate training and support.

Expectations

One means of measuring success or failure of GBIS is to ensure that an understanding of 'what can be expected' is communicated. The GBIS document entitled "Strategies for the 1990's" identifies expectations in four areas:

- **Product/Application expectations** outline the types of new or expanded applications that will likely occur. These include areas such as increased graphic/non-graphic links; three-dimensional plans; linkage to networks at the provincial and federal level; vehicle dispatch and location monitoring, etc.
- **Financial expectations** include a continuation of the "user-funded" philosophy.
- **Project Management expectations** highlight the continuation of the "user-driven" approach under corporate guidance. Also plans and strategies will recognize changing technologies and

the dynamic organization.

- **Hardware/Software expectations** include an increase in special application packages, increased networking and self-sufficient operational units.

Growth Strategies

To manage the expectations and achieve project goals, it is necessary for GBIS to expand in several directions. This is to occur through the implementation of specific growth strategies, such as:

- Increasing basic geographic information relative to the existing "as-built plan" situation.
- Broadening the scope of basic information to include proposed developments and facilities.
- Enhancing the capability for linking graphic and non-graphic data.
- Broadening the type of application, (e.g., facilities management, geoprocessing, dispatching, vehicle location, etc.).
- Increasing the number of users of the system, both internally and externally.
- Providing adequate training, education and user support.

Hardware/Software Strategy

In order to ensure that the GBIS can develop in a manner that allows for continual growth while providing stability through changing technology and organization, eleven directional statements were made concerning hardware and software. Some of the key areas included decentralized processing and storage with corporate storage of common data, recognition that the technology must accommodate organizational changes, identification of a corporate graphics "backbone", emphasis on linking graphics, and business systems.

Partnerships

Thus far, the GBIS Project has been successful, and will continue to make progress because it is based on co-operation, sharing and people. The following list identifies the types of groups that will be needed as formal or informal partners to achieve the ultimate goals:

- City departments.
- Industry partners that have information or facilities in Edmonton that would benefit other users, such as Northwestern Utilities, Canada Post, etc.
- Supporters which ensure the effective development of GBIS, such as senior City decision makers.
- Suppliers of services, hardware and software.
- Educational institutions for training, research, etc.
- Private industry to whom City staff would provide advice, support and on-site training.

- Other municipalities to whom the City could assist in GBIS implementation.
- Public users, including developers, surveyors, consultants, business, community organizations and private citizens.

Training and Support

Implementing a technology such as the GBIS into City operations can result in major changes to an individual's work environment and methods. To ensure optimum utilization of the system, training programs for City staff in graphics technology are required. The need for day-to-day end user support is as important as formal training. This support must be of two types; systems support for the technology, and applications support or user support in understanding the information, data or standards.

Project Organization

In order to increase communication, integration, and effectiveness, the strategy identified the need for a revised Project organization. Major features of the structure include:

- Identification of departmental graphics co-ordinators (10), as well as co-ordinators for each major user group within the departments.
- Utilization of departmental systems co-ordinators which have played a major role in business systems over the last few years.
- Establishment of application user groups or special interest groups to enhance communication between individuals with similar applications or problems.

Although not identified in the strategy, a corporate graphic standards committee is being established to monitor and establish standards and guidelines.

In keeping with the thrust of decentralized activity, co-operation and sharing, the GBIS Project Office which is responsible for overall project management, will continue to be relatively small (4-6 staff).

4. CONCLUSIONS

Edmonton's GBIS is built on a foundation of sharing, co-operating and integrating. The project motto "Corporate Co-operation, Together We Make It Happen" emphasizes this essential but somewhat unique approach to GIS implementation. This co-operation and base level project support has sustained GBIS through significant economic, organization and technological change and allowed it to grow and prosper.

As we look to the future, there are many uncertainties facing not only GBIS in Edmonton, but municipal GIS projects around the world.

However, based on our experience, there are many certainties that our GIS projects must be prepared to address. Some of them include:

- The basic business of municipalities will not change substantially.
- Technology is not a major problem and will likely provide more capability than we can effectively use.
- Internal procedures, "turf protection", and data inconsistencies will continue to be major obstacles.
- Organizations will continue to change and the GIS strategy must recognize the effect of delayering.
- Public demand for access to data will increase.
- Public demand for protection of privacy and confidentiality will also increase.
- Technology will continue to change so by the time you install the system that you spent so much effort ensuring that it was the latest and greatest, it will not be the latest and greatest.
- Implementation of GIS must recognize that most human traits have not changed substantively so our end users will:
  (a) learn incrementally as we all did from grade school to university;
  (b) be concerned about change and the risk to their job;
  (c) if they are managers, will likely be satisfied with their current information systems and not want to risk a major change; and
  (d) expect all of the results, but little of the risk.

5. ACKNOWLEDGEMENTS

To specifically acknowledge the individuals who directly contributed to this paper would be impossible because the thoughts, ideas, words and effort comes from so many of the individuals involved in GBIS. However, it would be a grave oversight to not acknowledge the efforts of the 100 to 200 individuals who have in some way contributed to making GBIS a success so this paper could be written at all. Thanks.

Edmonton/GBIS Facts

Population - City - 614,665 (1991)
Region - 800,000 approximately

Area - 700 square kilometres (270 square miles)

Land Parcels - 200,000

Civic Employees - 12,000
Total Departments - 15
City-Owned Utilities - power, telephone, water, drainage, airport, and transit.

Business Computers:

- Mainframe - UNISYS, IBM
- Minis - H.P. Dec. (6)
- Networks - many independent PC based networks with a move to token ring

GBIS:

- Intergraph based
- Minis - 2 Micro VAX
- File Servers - 6
- Terminals (Graphics) - 19
- Workstations (UNIX, PC MAC) - 160 (not including NUL)
- User Groups - 58
- Total Users - 250 est.
- Civic Departments/Agencies Using GBIS
  - City Clerk
  - Computing Resources
  - Ed Tel Corporation
  - Finance
  - Fire
  - Parks and Recreation
  - Planning and Development
  - Police Services
  - Power
  - Public Works
  - Transportation
- Outside Partners
  - Northwestern Utilities Ltd.
  - Videotron

GIS User Requirements
Besoins des utilisateurs de SIG

Linders, Dr. Jim

Not available at time of printing
Non disponible au moment de l'impression

Building the GIS Infrastructure in British Columbia

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Abstract

Since the mid-1970's, the British Columbia government has constructed inventory information systems based on computer mapping and GIS to manage the resources that are so basic to our economy. Most of these systems were developed to support the information needs of single departments/ministries. In 1986, the province started one of its first corporate data capture programs, called Terrain Resource Information Management (TRIM). In the meantime, the need for cross-departmental examination of resource management and social issues began to reflect the complex nature of our problems. But the decision support systems developed by individual departments were unable to identify, rationalize, and share data across departmental systems. In 1988, the Ministry of Crown Lands was given the task of corporately, restructuring land information. This paper describes our strategic approach and our progress in developing a GIS infrastructure over the past 3 years. The GIS infrastructure is comprised of an organization to manage it, policies and procedures that are the 'rules of the road' that govern its use, and finally the physical infrastructure itself that delivers the service.

RÉSUMÉ

Depuis le milieu des années 70, le gouvernement de Colombie-Britannique travaille à la mise sur pied de systèmes d'information d'inventaire faisant appel à la cartographie informatisée et les SIG pour assurer la gestion des ressources qui sont si importantes pour notre économie. La plupart de ces systèmes ont été créés pour satisfaire aux besoins en information des ministères à volet unique. En 1986, la province a entrepris l'un de ses premiers programmes gouvernementaux de collecte de données, appelé «Terrain Resource Information Management (TRIM)». Entre-temps, la nécessité de se livrer à un examen interministériel sur la gestion de nos ressources et les questions sociales a commencé à révéler la complexité de nos problèmes. Mais les systèmes appuyant la prise de décisions, mis sur pied individuellement par chaque ministère, n'étaient pas en mesure de relever et de rationaliser les données, de même que d'en permettre l'échange entre les systèmes ministériels. En 1988, le ministère des Terres de la Couronne a été chargé de restructurer la banque d'information gouvernementale. Ce document décrit notre démarche stratégique et nos progrès réalisés, au cours des trois dernières années, dans la création d'une infrastructure pour les SIG. Cette infrastructure se compose d'un organisme qui en assure la gestion, de politiques et de procédures qui régissent son utilisation et, enfin, d'équipements qui permettent la prestation des services.

1. INTRODUCTION

In 1988, an Order-in-Council designated the Ministry of Crown Lands (since renamed Environment, Lands and Parks) to consolidate all mapping systems across government. We interpreted the term "mapping systems" to mean "Geographic Information Systems" and thus, understood maps to be the spatial context for departmental data about the land base, its resources and even its demography. For example, mapping systems existed for the management of Water Licenses in which the maps served as an index to a textual database.

The common thread through the business justifications for each mapping system was the need for the province to manage its, Constitutionally-enshrined, natural resources. Last year, provincial natural resource revenues, including water license rentals, were in the order of $1.25 billion. Over 80% of B.C.'s exports[1] are based on our natural resources. Thus it is no surprise that sophisticated GIS for resource management developed. Between 1978-88, the provincial government and its Crown Corporations owned at least 8 mini-mainframe GIS. In addition dozens of standalone, microcomputer-based mapping systems had been acquired. As would be expected, each was developed to meet a finely-focused business need, such as the management of forest inventory for the determination of Annual Allowable Cut.

We decided against physical consolidation of all mapping systems and GIS in government under the organizational roof of the Ministry of Environment, Lands and Parks because most were obviously business systems that supported the resource management mandate of the various ministerial departments. Counting regional staff who used and maintained such systems, the new organization might have topped 1000 people. Instead we opted to leave the mapping systems close to the businesses they served and we would try to achieve virtual consolidation through cooperation among the various departments.

2. Belling the CAT

The Surveys and Resource Mapping Branch of the Ministry of Environment, Lands and Parks has been mandated to lead this virtual consolidation. The reasons behind this goal could be summarized as:

a. need for shareable GIS data to address major issues that cross departmental lines

b. need for physical connectivity to enable sharing and access to departmental GIS data

c. need to maximize the return on each departmental GIS expenditure.

Native Land Claims, Sustainable Development Objectives, Forest Resources Commission, and Provincial Land Use Strategy are examples of major issues that cross departmental boundaries. Ideally each department would contribute GIS data to enable construction of say, resource valuation models by clients like the Ministry of Native Affairs. Lack of data standards, reference standards, and different (often undocumented) data management practises combine to stifle shareability of departmental GIS data.

Physical connectivity would seem to be a simple issue concerned with providing connections to communication networks. The predominant use of GIS in the provincial government will be in dozens of regional and district offices. The custodians of much of the mini-mainframe GIS data are located in Victoria. Copy management, seamless design and protocol

issues can constrain connectivity. Most Geomatics standards are struck on tape-based models. Ideally, we should be planning for switchable, broadband networks.

The need to maximize return on GIS investment could be realized by minimizing the duplication of data capture and maintenance effort. The Ministry of Forests could avoid costs of almost $3000[2] for every topographic map if it was accessible in a standard computer readable form. Province-wide this ministry could avoid costs of up to $20 million.

The sum of these imperatives pointed to a need for a strategy. The Surveys and Resource Mapping Branch engaged DMR Consulting to draft a strategy[3] for the development of an enterprise-wide GIS infrastructure. The strategy identified three major components:

1. Organization to guide strategy implementation
2. Land Information Management Framework
3. Land Information Infrastructure

The migration strategy and action plan was defined for a 7 year horizon and was accepted by a Cabinet.

3. ORGANIZATION

All enterprises have a financial comptroller function that sets the standards for financial systems. In British Columbia, the Office of the Comptroller General accomplishes this through a set of Financial and Administrative Operating Procedures that governs all financial data. Adherence to these procedures is compulsory and is the basis for audit.

DMR suggested a similar organization would have to be struck and empowered to control the reliability and integrity of land information systems across government. The Government Land Information Data Exchange (GLIDE) was created within the Surveys and Resource Mapping Branch. It is staffed by seven professionals who are leading the GIS Infrastructure project. Any departmental GIS development project larger than $100,000 is ultimately reviewed by this group which makes recommendations to Treasury Board.

4. LAND INFORMATION MANAGEMENT FRAMEWORK
Policies, Procedures, Standards and Guidelines

GLIDE's equivalent of the Comptroller General's Operating Procedures for financial systems is a policy called the Land Information Management Framework (LIMF). DMR and Sierra Consulting were engaged to draft a management framework in consultation with line departments. We wanted to ensure that the LIMF would be practical and that the line departments would recognize the advantages of conforming. We sought the advice of 'central agencies' in government that routinely set policy. The 3 volume LIMF[4] was finally published in December, 1991 after a 2 year gestation. It consists of:

1. Management Overview
2. Systems Planning and Development Framework
3. Information Management Policies

and is effectively the 'rules of the road' that anyone must follow to operate within the Land Information Infrastructure. GLIDE is currently delivering information (marketing) seminars on the LIMF to all provincial GIS data custodians and systems professionals. They have also delivered sessions to GIS consultants, vendors and the data capture community to make them aware of the

policy and procedural issues they must address if they are to deliver GIS services to provincial government departments. In a sense we are counting on the professional discipline of this community to reinforce compliance by their government clients.

The LIMF makes the fundamental assumption that all data will reside with the resource management departments that generate and manage the data. There will be no physical consolidation of the data. As an example, it is expected that the various aspects of land tenure[5] will continue to be managed as illustrated.

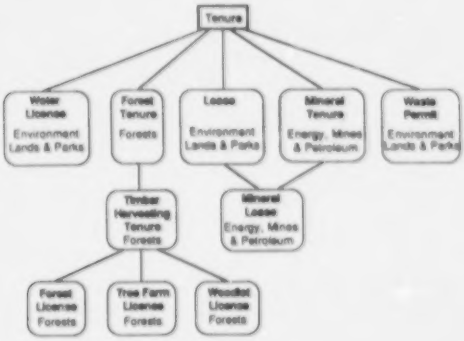

Figure 1 - Tenure Subclasses

The LIMF identifies three broad categories of GIS data - Corporate, Participatory and non-Participatory. Corporate GIS data:

1. are managed primarily as a service to other ministries and agencies;
2. provide a spatial reference or essential linkage with that of other public or private sector organizations; or
3. represent legal encumbrances on land.

Corporate GIS data has the highest level of data management guarantees in terms of metadata, geomatics interchange standards, update, access and security. Examples of Corporate GIS data are the Provincial Digital Topographic Atlas, and Crown Land Cadastre[6]. Conceivably, a provincial version of Statistics Canada's Area Master File might eventually be declared Corporate. The implication of Corporate data, is that it is so fundamental that its integrity must be preserved. For this reason, the custodian cannot unilaterally make changes to specifications, or even update the data without establishing a process for posting them. Participatory data, such as Forest Inventory is slightly less constrained. Both Corporate and Participatory data will be available throught the Land Information Infrastructure (LII). The non-Participatory category recognizes that there could be GIS data holdings beyond the scope of the LII.

The Systems Planning and Development Framework described in Volume 2 is like a generic template for system development. It is a self-help guide for the development of new GIS, or migration of existing GIS containing Corporate or Participatory data. Its purpose is to ensure that the subject GIS can be connected to the LII. It helps the line departments navigate through the Information Management Policies in Volume 3.

The Information Management Policies in Volume 3 cover:

1. Data Management
2. Applications Management, and
3. Technology Management.

Topics addressed under Data Management are the LII Repository, data definilton, data custodianship, data currency, data provisioning, data capture and acquisition, data updating, data sharing, data exchange, data security and access, and data marketing and pricing. By way of illustration, the data capture guidelines reference the North American Datum 1983 as the provincial standard and the Provincial Digital Topographic Atlas (which will be described in Section 5) as the geographical referencing framework. The data exchange guidelines state that the Spatial Archive and Interchange Format (SAIF) will be the basis for sharing data via the LII.

Applications Management policies were developed to ensure that applications accessing data via the LII through a direct interface would contain certain functionality, would be able to understand particular types of data, and would be designed on standard principles. One such principle would be independence of the application from any specific communications technology.

The Technology Management policies cover Data Base Management Systems, Computer Aided Design and Drafting and Mapping Systems, Geographic Information Systems, Data Capture Technology, Data Communications Technology, Data Delivery Technology and Technology Platforms. An examination of the policy for technology platforms would reveal that LII is committed to supporting multiple platforms, and in a way that is transparent to the user in the Corporate Domain. This pithy statement implies highly generic applications.

5. PROVINCIAL DIGITAL TOPOGRAPHIC ATLAS

Before delving into the Land Information Infrastructure, it is perhaps appropriate to examine one of the Corporate datasets that will be available through it. There are 3 discreet series of topographic data covering all of British Columbia. Ideally each would be generalized derivatives of the higher resolution data or multiple views of the same geographic object. There are still many technical difficulties to overcome and so we continue to meet the requirements of GIS users for different resolutions by maintaining each series as depicted. The data is structured identically using a few basic rules governing networks, drainage systems, closed areas and digital elevation models. From this common structure it is expected that specific GIS products will construct topology that is meaningful to their requirements[7] and in fact, this feature has been field tested with over a dozen different GIS, CAD and computer mapping products. Common data structure means GIS products operate predictably with each of the 3 series.

The 1:2 000 000 series covers all of British Columbia in a single file and will be availabe by the end of April, 1992.

The 1:250 000 series will require 84 files of National Topographic Series data. This data was originally scanned from reprographic separations by Energy, Mines and Resources Canada and is now being structured to provincial standards. So far about 30 of the 84 files have been structured for universal GIS use and the remainder will be ready by December, 1992.

The 1:20 000 series will require 7000 files to cover the province. This series is being compiled photogrammetrically under a program called TRIM, Terrain Resource Information Management. TRIM compilation has been on-going since 1986. To the end of March, 1992, over $30 million has been expended and it is expected that another $40 million[2] will be required to complete this program by 1995/96. TRIM is the major geo-reference data source for operational resource management, such as forest inventory, or detailed soils inventory.

6. INFORMATION INFRASTRUCTURES

In a recent magazine article[9], Michael Dertouzos describes his vision of a national information infrastrucuture, largely defined by the communications networks that support it. He compares the current state of networks to dirt roads of the early 1900's which bear no resemblance to the current national highway system. He describes infrastructures as having simple but powerful properties - widely available, easy to access, and deliver service that can be leveraged.

In British Columbia, we seek to develop the LII to deliver GIS data anywhere in the province anytime. Access will be simple as long as the user's access technology respects our interface specifications and protocols. The infrastructure's ability to deliver data services to consumers is predicated by the cooperation of the data custodians in conforming to the LIMF. It is expected that the data service that will be delivered would be highly leveraged by consumers who add value to it, analyze it , or make better/more timely decisions from it.

Dertouzos further defines the information infrastructure in terms of its network, as having the following properties:

- flexible information transport
- common services, and
- common communications conventions.

Although he was writing about infrastructure, in general, these same properties apply to GIS infrastructure. Although a subset of the former, in the first half of this decade GIS network requirements could be pushing the prevailing state of the public networks; Model T's on rutted, dirt roads.

Flexible information transport implies the capability to move GIS data with selectable volume/speed, integrity, reliability and security levels. We can anticipate that the GIS data model[10] must accomodate vector and raster definition of geographic objects that may be defined in 2, 3 or even 4 dimensional space, with linked text attributes and labels. Conceiveably, voice and video data may have to be recognized by the GIS data model. Such a data model must be serviced by flexible information transport.

Common services for a GIS infrastructure will include:

- a repository (index of what GIS data exists and who holds it)
- universally shared GIS data (Corporate data in our case)
- access to the data offered by those data custodians who subscribe to the infrastructure, and

- some minimal but common level of application functions.

The GIS infrastructure is not a universal GIS. However some GIS-like query capability for a more-surgical downloading of data from custodian to user, could alleviate the pressure on network bandwidths.

Common communications conventions of course refer to standards. Rather than an Esperanto analog, which implies learning a new, universal language with intuitive cues to our native languages, the communications convention recognizes and promotes the use of numerous languages while allowing easy, precise translation. The conventions for infrastructure development in British Columbia are based on the Spatial Archive Interchange Format (SAIF), the draft national standard adopted by the Canadian General Standards Board.

7. B.C.'s LAND INFORMATION INFRASTRUCTURE (LII)

So far my description of GIS infrastructure has been generic. Our implementation in British Columbia is the Land Information Infrastructure (LII). It is being managed by the GLIDE Unit of my branch and the work is being carried out under contract to MacDonald Dettwiler Associates (MDA) of Richmond, B.C. Rather than reference each document submitted by MDA in the body of this paper, I will simply reference them as a block[11].

Fundamentally, the LII will be 4 subsystems:

- LII Common Data Model and Query Language
- client/server communications
- servers and databases internal to the system, and
- User Access Terminal (UAT).

The components of the design architecture are illustrated in Figure 2.

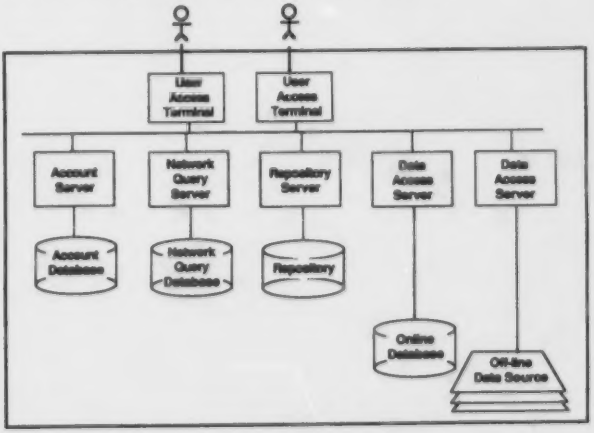

Figure 2 - LII Design Architecture

The UAT is the client's window for viewing, ordering and receiving GIS data through the LII. UAT software will interface to existing personal computers, workstations and standard terminals, each running their own native programs.

The servers and databases for the repository, network and accounts are examples of ones that are internal to the LII. The Repository is a database about data. A part of the Repository, known as the Directory, can identify for the client all databases known to the LII . Another part of the Repository, known as the Dictionary, contains information about the data models that describe each custodian's data and how to translate them to the LII Common Data Model in conformance with SAIF.

The Network Query component manages the processing of queries generated between the multiple UAT technologies owned by clients and the multiple database environments of the data custodians. The role of the Accounts component is self-explanatory.

The Data Access Servers are custodian-owned interfaces between the LII and the source databases, that handle some of the query and data model translation. This will be effected through a multi-layer schema consisting of local, export, conforming and federated layers. Each level defines a degree of integration with the LII and with other data sources.

The LII will use a Common Query Language based on the Common Data Model. It will be based on a superset of SQL with extensions for geographic data. As was the case with interchange formats, we are entering an area that will need standardization across the GIS community.

The polyglot nature of the LII environment dictates the need for the communications network to conform to the International Standards Organization's seven layer reference model for Open Systems Interconnection.

8. CURRENT STATUS OF THE LII DEVELOPMENT

The LII will be implemented in 4 phases by 1998. The current contract covers the first two phases for a 30 month term that began in November, 1990.

One year from now, MDA will be delivering a Phase 2 prototype that will not be a "throwaway" in the usual sense of the term. The internal servers and databases will be combined in a single database that will reside on a single host computer. The prototype will be designed for simultaneous access for up to 12 users; 11 nodes dedicated to Victoria and 1 for Prince George, some 800 kilometres away. It will provide on-line access (defined as being electronically connected to the LII and accessible without human intervention) to the 3 Corporate databases designated thus far:

- the Cadastral Data Management System managed by the Surveyor General Branch of the Ministry of Environment, Lands and Parks, currently runs under ESRI Arc/Info on UNIX[12]
- the Crown Land Registry Information System managed by the Surveyor General Branch operates from an SQL/DS relational database under VM/CMS
- the aforementioned Provincial Digital Topographic Atlas managed by the Surveys and Resource Mapping Branch of the Ministry of Environment, Lands and Parks will be accessed on DEC Rdb running under VAX/VMS.

Off-line access (access that will require human intervention to fulfill a request for data) is being planned for up to 33 Participatory databases which would appear in the Repository in varying degrees of completeness. The main variations will occur in the dictionaries that describe the source data model. The candidates include Agricultural Land Reserve, Archaeological Sites, Enumeration Data (provinicial variant of Area Master File), Fisheries Stream Inventory, Forest Tenure, Geological Inventory, Growth and Yield (Forest), MAPS-BC and Water Licensing.

The single host computer will be a Sun Sparc Server running UNIX and the data base management system that has been selected is Sybase. Other options, particularly for the DBMS were thoroughly considered. The selection of a relational DBMS will result in a SAIF implementation that will be semantically, less sophisticated than in Phase 3, but that factor could not outweigh the risk in delivering a working Phase 2 prototype in 12 months. SAIF will be implemented using User Syntax Notation (USN) for the data definition language.

Phase 2 is directed to serve the ministries of the provincial government. Universal access to the public is planned in subsequent phases. At this time, we are planning to develop the UAT application interface only for MS Windows and use a cross-platform library to port it to other platforms, like Macintosh, Presentation Manager (OS2), and RISC workstations. Representative examples of these other platforms will be used in the Phase 2 prototype.

MDA will be delivering the UAT and Data Access Server specifications within the next six months. These two important milestones will open up the LII (even as Phase 2 is being developed) to third parties. The specifications will be needed for constructing or migrating database management systems for more than 100 departmental custodians (sources), and more importantly, for delivering GIS analysis systems that will interface to the UAT for which we estimate up to 5000 clients.

5. FUTURE OF LII

Over the past ten years, we have been developing cutting edge GIS capability in British Columbia that started with a topographic data capture program called TRIM. Initially we preferred to lie low because we lacked the absolute faith of Kinsella's character who built a baseball stadium in his cornfield, knowing in his heart that 'they would come'. In the case of TRIM, they did not come as quickly as we had predicted but now 5 years later the bleachers are sold out every day.

Although Phase 3 has been mapped out, our experience with TRIM prompts us to analyze the performance of Phase 2 before we start crow about our plans beyond 1993. Rather than speculate, I would like to raise three concerns that may affect our success, even in the short term.

The first is the need for better knowledge about what data sharing will accomplish. We all appreciate the upside, but what are the downsides to open, pervasive and faceless access? What downsides to security, privacy, integrity, and intellectual property are presented by an ability to recombine and synthesize data from multiple sources? Our policy frameworks are mainly designed for the controlled, limited markets that we envision today for a GIS infrastructure, but how robust are they, when the GIS infrastructure inevitably becomes part of Dertouzos' more ubiquitous information infrastructure?

The second is a need for better understanding of the concept of information utilities. In embracing the concept, have we really examined the implications, particularly where public

information is concerned? Although there are several instances of embryonic land information utilities in Canada, they are not utilities in the usual, regulated sense. What are the risks; how are they shared? Case studies of the ones that do exist should be encouraged.

Finally, I am concerned about the ability of our communications networks to keep pace with the initial stages of developing a GIS infrastructure. Every telecommunications company in Canada has a capital build program that will eventually meet our requirements but the question is timing. For the networks to be there, capital build programs must start 2-3 years in advance of when we need them. Confidence in the ability of the telecommunications companies to read the market demand may be misplaced; some did not anticipate the market on facsimile transmission. This is not a comment on the fallibility of market forecasters but a wake-up call to the geomatics community to articulate its downstream network requirements. Recently the Canadian Space Agency visited Vancouver to seek input to the Long Term Space Plan (LTSP). As rivetting as the 2 dozen briefs were, Dr. Larkin Kerwin raised the most interesting point at a luncheon at the end of the session. For all the proposals to put up the next generation of Earth Observation Sensors (EOS), for all the proposals to build the analytical tools for end-to-end systems, no one suggested that the LTSP should have linkages to Canada's long term telecommunications planning. This would be a strategic alliance of two of Canada's strongest suits in technology.

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The Use of GPS for GIS
L'utilisation du SPG pour les SIG

Wells, Dr. David

Not available at time of printing
Non disponible au moment de l'impression

INNOVATION IN GIS EDUCATION AND TRAINING PROGRAMS

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Abstract

The Context ...

Widespread demand exists for highly trained geomatics personnel at the operational, managerial and executive levels, but responsive training programs are in short supply (Geomatics Human Resources Planning Study, November 1991, p. 1). While progress has been made in the development of GIS training by vendor-specific training courses, college and university diploma programs and professional development initiatives, there is much work that could be done to create customized courses that would respond to sector-specific education and training needs. Such courses would develop an awareness of the capability of spatial information analysis, its potential for efficiencies and value-added enhancement to traditional work formats in many fields.

Whether you are a municipal planner, forester, agrologist, oceanographer, geologist, transportation planner, surveyor or business location consultant, the traditional approaches to spatial analysis have failed. Users have found that paper maps, planimeters, calculators and manual filing systems are inadequate because they are not suited to accessing data easily. Often information is required from several data bases, with completely different data formats.

The solution lead-organizations are turning to is the computer-based geographic information system. The benefits achieved by integrating the most popular computing tools such as LOTUS 1-2-3(R) and dBASE(R) into a spatial analysis system on the micro-computer are being used in a multitude of applications around the world. And with the advent of the mini-computer, the proliferation of GIS has further expanded making training a vital organizational function.

A Response ...

Carleton University has developed three innovative approaches to respond to GIS education and training needs: the establishment of the Geomatics Training Institute, the development of an Objective Numerical Generalization System and the creation of the ZAPPER (R) Animation System.

NOUVEAUX PROGRAMMES D'ÉTUDES ET DE FORMATION SUR LES SIG

RÉSUMÉ

Contexte

Malgré la forte demande pour l'obtention de personnel hautement spécialisé en géomatique, tant dans les secteurs opérationnel et gestionnel que dans celui de la haute direction, les programmes de formation adaptée ne font pas légion (Étude sur la planification des ressources humaines en géomatique, novembre 1991, p. 1). Les cours offerts par les fournisseurs, les programmes d'études collégiales et universitaires et les iniatives de perfectionnement ont certes contribué à faire progresser la formation sur les systèmes d'information géographique (SIG), mais il reste encore beaucoup à faire pour que soient dispensés des cours sur mesure capables de répondre aux besoins précis des secteurs en matière d'études et de formation. Pour bien des domaines, cet enseignement ferait ressortir les possibilités qu'offre l'analyse des données spatiales et les gains qu'elle peut procurer sur les plans de l'efficacité et de la valeur ajoutée par rapport aux méthodes de travail traditionnelles.

Tant pour le planificateur municipal, l'expert-forestier, l'agronome et l'océanographe que pour le géologue, le planificateur en transports, l'arpenteur ou l'expert-conseil en bureaux d'affaires, les approches traditionnelles à l'analyse des données spatiales ont échoué. Les planimètres, calculatrices, cartes sur support papier et systèmes de classement manuels se sont révélés, pour les utilisateurs, des outils inadéquats du fait qu'ils ne permettent pas d'accéder facilement aux données. Souvent, il arrive que l'on doive consulter plusieurs bases de données dotées de structures complètement différentes.

Pour régler ce problème, les organismes directeurs recourent maintenant aux systèmes d'information géographique exploités sur ordinateur. Les avantages de l'intégration des outils informatiques les plus courants, tels LOTUS 1-2-3 (MD) et dBASE (MD), à un système d'analyse de données spatiales tournant sur micro-ordinateur se retrouvent dans une multitude d'applications partout dans le monde. De plus, l'arrivée du mini-ordinateur a entraîné une véritable prolifération des SIG, rendant ainsi la formation vitale pour tout organisme.

Solution

Pour combler les besoins existants en matière d'enseignement et de formation sur les SIG, l'Université Carleton a pris trois initiatives novatrices : l'établissement de l'Institut de formation en géomatique, la mise au point du Système de généralisation numérique objective et la création du système d'animation Zapper (MD).

Geomatics Training Institute GTI

GTI was created to expand the opportunities for GIS training at different organizational levels as well as to provide an option for the custom design of education and training programs to respond to sector-specific organizational demands.

The GTI technical training and seminar series is a hybrid of two earlier GIS education and training initiatives. First, GIS courses have been offered since 1990 as part of Carleton University's School of Continuing Education program. Second, Intera Tydac has offered SPANS (TM) purchaser training courses for a number of years. By combining the two programs, it has been possible to design a richer and more responsive set of GIS training programs.

GIS Courses using the TerraSoft Platform
School of Continuing Education, Carleton University

GIS training courses at Carleton University are offered in one- or two-day formats and to date 75 people have been exposed to GIS concepts and capabilities. TerraSoft is the selected platform because of its dual capability to support raster, vector and polygon methods as well as to mix them for maximizing analytical and cartographic output options. Course formats provide trainees with a conceptual understanding of geographical information systems, and the structure and productivity enhancement components of the particular software platform. For instance, a single graphics environment integrates all data entry and editing (digitizing, COGO (survey data), textual data loading), and ad hoc analytical functions (e.g. overlay, queries, buffering, proximity). Demand for the courses outstripped the capability of supply, given the great variety of computer-based training courses provided by the School--many of which feature in Carleton's unique Microcomputer Skills Application Certificate.

GIS Courses using the SPANS Platform
Intera Tydac Technologies Inc. Carleton University Development Corporation

Intera Tydac training programs have become an essential part of overall product development. SPANS training is provided in a multiple-level program that covers an introduction to the system in a five-day basic course, a two-day upgrade and a three-day advanced modelling course. Training has been delivered either at a specially-designed learning centre at Intera Tydac or at customer locations.

To augment the structured training programs, Intera Tydac created the Institute for GIS in Education (IGISE)--an independent, nonprofit institution that is sustained by sales of SPANS GIS software to educational institutions at prices substantially lower than commercial rates. IGISE has developed GIS learning units which are used for in-class teaching and for self-directed learning objectives.

Objective Numerical Line Generalization

Some fifteen line generalization algorithms have been developed over the past decade. Although significant advances have been made regarding simplification criteria little has been written, let alone coded, for selection criteria of features in the map generalization process. As drainage networks are usually represented as systems of single lines, this class of common map features is used for development of selection criteria in combination with previously existing simplification algorithms to produce an automated generalization system.

River network entities are viewed as linear features built up from two types of components - straight line segments made up of two or more co-ordinate pairs, and critical points. Critical point detection is conducted before line generalization, and the location of these points included in a generalized map data base, along with the co-ordinate points drawn from the line generalization algorithms.

Two river data structures are explored - a river-by-river structure, and a nodes and segments structure. Selection criteria relfecting river length, drainage density, 'importance' of the river, and spacing between river system features are combined with simplification algorithms into a river network objective numerical generalization system.

The ZAPPER Animation System for Line Simplification and Smoothing

The purpose of the ZAPPER (R) Animation System is to demonstrate the effectiveness of and differences between several cartographic line simplification and smoothing algorithms, and to dynamically animate the simplification/smoothing process using computer graphics techniques.

Point reduction or line simplification is applied to a map when there is a requirement to reduce the number of points necessary to represent the linear features of the map, yet retain the basic caricature or shape of these features. Smoothing is generally applied to improve the aesthetic qualities of a map. Many algorithms have been devised for the purpose of point reduction and smoothing. Each has its own unique method of line simplification or smoothing and each produces different results.

Animation techniques provide immediate feedback when experimenting with cartographic lines of different curvilinearity and point densities. The user is not only able to visualize the algorithm more effectively, but is able to follow, in real time, the simplification/smoothing sequence as the algorithm operates on the cartographic line. Computer animation creates an effective means of understanding the operation, implementation and differences of these various algorithms.

The ZAPPER (R) Animation System was designed as a demonstration utility and educational tool for cartographic line simplification and smoothing. A broad cross-section of simplification algorithms, from local to global line processing, are available, as well as several line smoothing algorithms that use various coordinate averaging techniques. The map overlay capability provides a visual comparison between the original and simplified or smoothed maps. A simple digitizing utility provides a method of data input to permit experimentation with different line shapes. A statistical utility provides a useful set of simple and comparative statistics for quantitative analysis of the algorithms. The ZAPPER (R) Animation System provides an easy to use, animated, graphics-based visual environment in which to compare and contrast a diverse range of cartographic line simplification and smoothing algorithms.

GTI Education and Training

The Geomatics Training Institute represents a fusion of GIS training initiatives at Carleton University and Intera Tydac Technologies Inc.. The result is a public/private sector alliance of expertise and resources to enrich GIS course development and delivery. Inaugural training programs were offered in January 1992 and consisted of a Technical Training Series for SPANS users as well as a Seminar Series with a general GIS educational focus. The quality of GTI courses is assured by a content advisory group made up of academic, industry and educational design personnel.

Balsam Lake
Aquatic Resource Management
GIS

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and
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ABSTRACT

The Trent-Severn waterway is a nationally significant and historic system of lakes, rivers, canals and locks that link Georgian Bay on Lake Huron to the Bay of Quinte on Lake Ontario. With approximately 6000 kilometres of shoreline through the heart of Ontario's recreation land, the waterway is a favorite of cottagers and tourists alike.

Administration of the waterway is the responsibility of the Trent-Severn Waterway (TSW) group of the Canadian Parks Service, Environment Canada. With upwards of 1400 applications a year for in-water development and 400 plans for changes to land use, TSW decided to investigate the use of GIS technology as an operational tool in their management of the aquatic resources.

This paper outlines a cooperative pilot project involving six agencies to develop and implement an prototype aquatic resource management support system utilizing GIS technology.

RÉSUMÉ

La Trent-Severn est une voie maritime historique d'importance nationale. Cette voie navigable est un système de lacs, rivières, canaux et écluses qui relie la baie Georgienne (lac Huron) à la baie de Quinte (lac Ontario). Avec 6000 kilomètres de berges en plein coeur de l'Ontario, la Trent-Severn attire aussi bien les touristes que les propriétaires de chalets.

La voie navigable est gérée par le groupe Trent-Severn (TSW) du Service canadien des parcs d'Environnement Canada. Chaque année, les gestionnaires font face à plus de 1400 applications de développement des berges ainsi que de 400 soumissions de plans qui impactent sur l'utilisation du sol. Le TSW a donc décidé d'investiguer la technologie des SIG comme outil de gestion des ressources aquatiques.

L'article décrit un projet pilote coopératif impliquant six agences. Le projet consiste au développement et à la mise en place d'un prototype de système de gestion des ressources aquatiques utilisant la technologie des SIG.

1.0 Introduction

TSW is responsible for the adminstration of in-water and, to some extent, adjacent upland development along the entire Trent-Severn Waterway. When a dredge/fill or change in land use application is received, it must be reviewed and evaluated for its possible impact on the operation of the Waterway or its aquatic resource ecosystem. Depending on the result of this review, an application may proceed with or without mitigating measures or be denied. Increases in the number of applications have resulted in TSW investigating the use of GIS technology as a more cost effective method to administer this process.

In September of 1990, a two year co-operative pilot project was initiated by TSW and EMR's GIS Division(GISD) to develop a prototype aquatic resource management application utilizing the PC based Intera Tydac SPANS GIS. Other participants in the project were the Ontario Ministry of Natural Resources(OMNR), the Ontario Ministry of Revenue(OMOR), the Department of Fisheries and Oceans(DFO) and Sir Sandford Fleming College(Lindsay Campus).

The overall objective of the project was to develop graphic and attribute files within SPANS that TSW staff could use in their evaluation of in-water development and change in land use applications. Information on natural resources, ownership and Waterways operations relative to each application could be quickly displayed and queried by the staff. The GIS would also provide a means for efficiently updating graphic or attribute files to reflect new information.

SCREENER is a 3rd party software package developed by Environmental and Social Systems Analysts Ltd.(ESSA) for federal agencies in support of the federal environmental assessment review process(E.A.R.P.). TSW are having ESSA customize SCREENER to accept data from the GIS to support their dredge/fill review process. Data from the prototype will be used to evaluate this software.

Upon completion, the prototype will serve as a model for the procedures and projected costs of full implementation along the entire waterway.

2.0 Roles/Responsibilities

At the beginning of the project, a meeting between representatives of all six agencies was held to identify each agencies possible involvement, roles and responsibilities. As a result of this meeting, the following was proposed.

TSW/GISD - share overall project management responsibilities and data.

OMNR - provide 1:10 000 scale data, technical support and assist with field work.

OMOR - provide 1:1200 scale assessment lot maps for the

		Balsam Lake shoreline with the corresponding assessment roll database and provide technical support.
DFO	-	collaborate on fish habitat information.
SSF	-	assist in data collection, conversion and input and provide technical support.

3.0 Methodology

Development of the prototype was carried out jointly between TSW and GISD's National GIS Technology Centre on Intera Tydac's PC based SPANS GIS. The area chosen for the pilot project was Balsam Lake, located in the Kawartha Lakes region of Victoria County, north of the town Lindsay, Ontario.

Throughout the project meetings were held to discuss various development stages; user needs study, database design, resource data requirements/collection, etc. The user needs study identified what TSW expected from the prototype and the data required to meet their needs. Based on this, existing sources for data were identified and data to be collected defined. The database chosen to contain the attribute information was dBASEIII. Database design was carried out for each data set and paper forms developed for field crews to collect the information. Hardcopy and existing digital map and attribute data were collected for input to SPANS.

All graphic and attribute information was to be integrated into SPANS to provide TSW with the capability to efficiently store, retrieve, analyse and display spatial and attribute data pertaining to dredge/fill applications, leases and licences and land use. The prototype was to be implemented, evaluated and documented in terms of the methodology and cost effectiveness for implementation along the entire waterway.

4.0 Data Sets

National Topographic Series(NTS) 1:250 000 scale digital data was used to provide a overall view of the area surrounding Balsam Lake. For the study area containing Balsam Lake, the roads, hydrology, contour, wetlands and woodland layers were extracted from the NTS 1:50 000 scale digital data and input to SPANS.

OMOR provided 66 1:1200 scale hardcopy assessment lot maps around the Balsam Lake shoreline and the corresponding assessment roll attribute database. The assessment maps were contracted out to be digitized and converted into SPANS format with unique identifiers for each lot. These lot maps provide the basic reference layer that the TSW staff will query when reviewing in-water development or change in land use applications. The OMOR database was provided in dBASEIII format with the assistance of Revenue Canada and input to SPANS.

Georeferencing of the assessment maps prior to digitizing turned out to be a difficult task. OMNR 1:10 000 scale hardcopy maps

covering Balsam Lake were obtained and digitized to provide a definitive shoreline reference. As accurately as possible, UTM coordinates were scaled off these maps and transferred to the individual assessment maps. After the assessment maps were digitized and input to SPANS, additional work was required to further refine their georeferencing and achieve better agreement with the OMNR digitized shoreline.

Data collected in the field for the prototype included spatial and attribute information on aquatic and upland vegetation, substrate, algae, offshore development, shoreline type, shoreline structures and fish habitat. Plots of the individual assessment lot maps were supplied to SSF students who, under a project of the Environmental Youth Corp(EYC), collected the information for each map. Once data collection was complete, the spatial information contained on each map were digitized with unique identifiers and entered into SPANS. The corresponding attribute information collected on the paper forms provided were keyed into individual dBASEIII files.

5.0 Data Transformation

As with most GIS applications, data sets available for the pilot project were referenced to different coordinate sets and different datums.

The SPANS GIS software requires that the user specify a projection and ellipsoid as part of its universe or study area definition. Data referenced to other projections or ellipsoids will be transformed into this specified universe projection resulting in one consistent data set. However, this projection transformation does not account for differences between coordinate sets or datums.

OMNR hardcopy maps display UTM coordinates derived using the MAY76 coordinate set and NAD27 datum. Since the assessment lot maps, and corresponding EYC data collected, were referenced to OMNR maps, the SPANS universe projection was chosen as UTM and the ellipsoid as Clarke 1866.

The NTS 1:50 000 digital map data was expressed in UTM coordinates derived using the NAD83 coordinate set and NAD83 datum. The NTS 1:250 000 digital map data was expressed in UTM coordinates derived using the NAD27 coordinate set and NAD27 datum.

Using the Geodetic Surveys of Canada's National Transformation software, all data sets were transformed to MAY76 coordinates on the NAD27 datum, then converted to UTM using the Clarke1866 ellipsoid.

6.0 Graphic/Attribute Data Integration

All spatial data, such as the assessment lot maps, aquatic vegetation sites and substrate types were entered into SPANS and transformed into quadtree map files. These individual quadtree map files for each data type were then merged into single maps

covering all of Balsam Lake. Each unique polygon on the single map layers had a point-in-polygon and corresponding identifier that would link it to its attribute data contained in the dBASEIII files.

Point files representing specific attribute locations, such as shoreline structures and fish habitat, were input to SPANS and buffered to create quadtree maps. The point files were also input into dBASEIII and merged with the corresponding attribute records. Once this was complete, the merged attribute file was re-imported into SPANS resulting in a point table file that could be queried on screen or used to reclassify the complete map by any column of attributes in the table. For example, the assessment lot maps were reclassified using the MOR zoning code to produce a land use map. This method of reclassification was used to produce new quadtree maps required in the prototype.

7.0 Analysis

The prototype will provide TSW with an inventory of aquatic resources and adjacent shoreline features information that they can display and query when evaluating in-water and change in land use applications. The separate layers of spatial information and their corresponding attribute table files within SPANS will provide a more cost effective method to assist TSW staff in this task.

Within SPANS, a unique conditions map and corresponding attribute table can be created by overlaying quadtree maps. This produces a single map that contains all of the information from each map used in the overlay. Using the unique conditions map and corresponding attribute table, and a rule base developed under TSW's guidance, SCREENER will be able to carry out the environmental assessment of the more routine applications. If an application is flagged by SCREENER, a more detailed evaluation will be carried out.

Using the modelling and analysis functions within SPANS, TSW will be able to develop and apply different studies such as proposed developments versus environmental effects scenarios, area of fish habitats and wetland changes.

8.0 Conclusion

The Balsam Lake aquatic resource management prototype GIS is the result of partnerships forged by six different agencies. Currently, the prototype is being implemented and it is anticipated that it will provide TSW with a cost effective tool in support of aquatic resource management and lands administration.

Development of the prototype will be documented according to the methods used, results obtained, costs, and will serve as a model for future implementation along the waterway.

9.0 Acknowledgements

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Improved Neural Network Techniques for GIS Classification Applications

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ABSTRACT

There are many applications where classification of raster-based GIS data is needed. Classification can take place at many levels, from landcover type determination from pixel images to analysis and decision making about land value. Technically, the most challenging aspect of implementing GIS classifiers is obtaining the classification rules. When few explicit rules are known, using a neural network to learn the rules is an effective solution. The neural network can be given example inputs and classifications and can automatically learn the rules it needs to correctly classify other data as well. Unfortunately, however, there are drawbacks to using a purely neural network approach, due to the lack of contextual data in individual raster cells. In this paper, we present a new technique for augmenting a neural network classifier with contextual knowledge in the form of IF/THEN rules. Our approach automatically converts these rules into an organization of small neural networks, so that the learning and robust, probabilistic qualitites of the neural network approach can be maintained throughout the classification system. We describe the approach and present examples of GIS images and their classification.

Méthodes améliorées à base de réseaux neuromimétiques destinées à des applications de classification au moyen de SIG

RÉSUMÉ

Il y a un grand nombre d'applications pour lesquelles une classification de données de SIG rastrées est nécessaire. La classification peut être effectuée à un grand nombre de niveaux, depuis celui de la détermination du type de couverture des terres d'après des images de pixels à ceux de l'analyse et de la prise de décisions en rapport avec la valeur des terres. Du point de vue technique, l'aspect le plus intéressant de la mise en oeuvre de classifieurs pour SIG est l'obtention des règles de classification. Lorsque peu de règles implicites de classification sont connues, l'utilisation d'un réseau neuromimétique constitue une solution efficace pour l'apprentissage des règles. Des exemples de données d'entrée et de classifications peuvent être fournis au réseau neuromimétique qui peut alors automatiquement faire l'apprentissage des règles qui lui sont nécessaires pour classer également d'autres données. Malheureusement toutefois, l'utilisation d'une méthode basée exclusivement sur les réseaux neuromimétiques présente des inconvénients en raison du manque de données contextuelles dans des cellules individuelles de données rastrées. Dans cette étude, nous présentons une nouvelle méthode d'amélioration d'un classifieur à réseau neuromimétique par une connaissance contextuelle prenant la forme de règles d'inférence. Notre approche permet de convertir automatiquement ces règles en une structure de petits réseaux neuromimétiques de manière à ce que soient maintenues partout dans le système de classification les qualités d'apprentissage et les robustes qualités probabilistes de l'approche faisant intervenir les réseau neuromimétiques. Nous décrivons l'approche et présentons des exemples d'images de SIG et de leur classification.

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I. Introduction

There are many applications where classification of GIS data is needed. In this paper, we will discuss classification of raster-based data. Classification can take place at many levels. At the most primitive level, pixel-based imagery from aerial or satellite photography can be classified into landcover types. Alternately, roads, lakes, and other features can be identified. At higher levels, previously classified raster data can be further analyzed. For example, consider the problem of identifying suitable habitat areas for marine mammals. GIS layers indicating water, shoreline type, presence of development, etc., would be used to classify the appropriate regions.

Technically, the most challenging aspect of implementing GIS classifiers is obtaining the classification rules. There are three general techniques for obtaining the rules: 1) obtaining the rules from human experts [Ton, et. al.] 2) obtaining parameters for generic rules from statistical analysis of images [Pereira & Itami] and 3) obtaining the rules from a learning system. Technique 3 is appropriate when little is known about either the form or the parameter values relevant for classification, because the learning system discovers rules from sets of "training inputs," which are example data and classifications provided by the user. The neural network fits into this category. Although there are many approaches to learning [Duda & Hart], the neural network approach is attractive for several reasons:

1. *It is widely applicable:* It can be shown that a neural network can learn arbitrary functional mappings from input data to classification [Rumelhart & McClelland].

2. *It generalizes:* Although some neural models generalize better than others, the most popular neural network approaches derive decision rules that cover cases not explicitly used in the training set.

3. *Its implementation is conceptually simple:* The design of individual neurons in a neural network is quite straightforward, and the connections between the neurons is, in most implementations, simple and regular. Thus, there is no major control structure or data flow complexity. The essense of what the neural network learns is encoded in the connection strengths between neurons: how much each neuron in the network affects the others.

In the following sections, the use of neural networks for GIS classification applications is discussed. In section II, we describe methodologies for connecting neural networks to the GIS for training and for classification. Shortcomings of the traditional neural approach are described in this context. Section III presents our approach for augmenting the neural network architecture with contextual information to improve on these shortcomings. Section IV presents an example implementation of our approach, along with actual GIS data and its classification by our system. Finally, we present conclusions about the work and its continuation.

II. Using Neural Networks for GIS Classification

In this section, we will consider classification problems where the goal is to classify each cell in a GIS database into two or more predefined categories. Classifying pixel images into landcover types, identifying geographical features, and estimating land value, suitability for development, or agricultural potential from data classified into lower-level categories are some typical examples. The techniques described here can also be generalized to problems where classification is not at a cell-to-cell level.

A neural network can be thought of as a box that accepts a set of input values, producing a set of output values. A classification neural network could be implemented as having one output, with the numerical value of the output representing different classifications, depending upon which range of values it falls into. However, in this paper, we will consider the neural network to have as many outputs as there are categories. With this approach, the output

with the highest value indicates the class. Because outputs corresponding to all of the categories are available, one can see how definite the score for the classification is in comparison to the scores of the other categories.

The most obvious way to implement a neural network for classification is to connect the network inputs to the attributes of one GIS cell, as shown in Figure 1a. If the information in the cell is simple Red, Green, and Blue values, for example, the neural network would have three inputs. For many applications, information from neighboring cells is also useful for classification. Additional inputs from neighbors can also be used, as shown in Figure 1b.

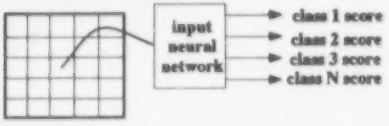

Figure 1a. Interfacing to one cell

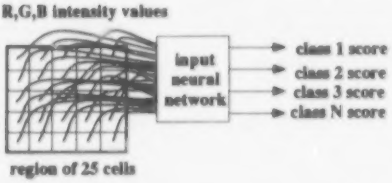

Figure 1b. Interfacing to a Neighborhood of cells

The above approach requires that the neural network derive all knowledge needed for classification from the information format stored in the GIS cells. However, there are cases where other derived information is known to be useful. For example, quantities such as "maximum brightness of spectral bands," average change in land value over the last 3 years," may be relevant. The neural network approach can be generalized by using conventional software to provide these quantities as additional inputs to the network.

II.2. Two Shortcomings of the Neural Network Approach

The neural network approach described above is effective for many classification problems. There are, however, some drawbacks which arise due to some inherent properties of GIS data. These shortcomings are enumerated in the following paragraphs:

II.2.1. All knowledge Must Come from Examples

The only way to transfer knowledge to a traditional neural network is to give it training examples. This is an undesirable state of affairs if significant knowledge about classification is known. For example, if a human expert knows that a certain type of pine tree is more likely to be found below an elevation of 2000 meters, training examples would need to be found in which elevation distinguishes between the pine and other similar growths. Examples of cells that otherwise have similar attributes, but in which the pine occurs below 2000 meters and other species occur above 2000 meters would be needed. It would be much more straightforward to encode the knowledge explicitly, rather than going to all this trouble. For example, a rule explicitly stating

```
IF (elevation < 2000)
THEN (prefer-classification PINE)
```

would be a much more satisfactory solution than searching for appropriate training examples in the GIS database.

II.2.2. Reasoning About Contextual Properties is also Needed

Human experts rely heavily on contextual information when classifying images. This kind of reasoning is needed to disambiguate between classes on the basis of how much sense it makes for each class to be at the particular geographic location of interest. For example, to identify suitable habitats for certain mammalian species, it is important to distinguish between land/water boundaries that have direct access to the open sea and land/water boundaries that are further inland. This kind of reasoning is not feasible with pixel-level neural networks alone, because they use only information about the pixels in the area being classified. To include much larger pixel regions would not only add to the computational complexity, but would lead to major design problems in terms of normalization and providing the proper invariance relations [Thacker & Mayhew]. The needed contextual relationships, such as "distance from sea," can be encoded in explicit IF/THEN

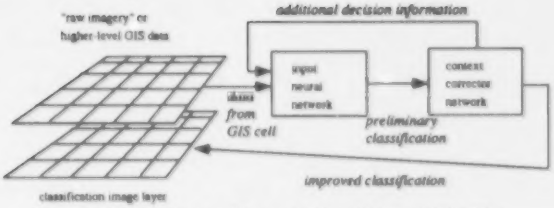

Figure 2. System Diagram of Improved Neural Network Classifier

rules. However, the information to compute these relationships resides at points often far-removed from the cell being classified. The technical problem, then, is to provide a general-purpose way to specify and access the appropriate data for use by IF/THEN rules.

III. A New Approach to Augmenting Neural Networks with IF/THEN Rules

As discussed in Section II, two major drawbacks of a pure neural network approach to classification of GIS data can be overcome by augmenting the neural network with IF/THEN rules that access data both from the cell being classified as well as from other areas in the raster image. In this section, we present a technique for combining these capabilities in a conceptually clean architecture.

A system level diagram of the overall approach is shown in Figure 2. As shown in the figure, the GIS holds all of the data used throughout the processing. A "traditional" neural network is the first to process the GIS data. Initial classification and feature extraction is performed at this point. The results of the classification are sent to the "Context Corrector" component, which uses the IF/THEN rules to improve on the classification. Some of the new knowledge generated by the expert system is fed back to the neural network, as shown in Figure 2. This feature, described in more detail in Section III.1, allows the learning and comparison capabilities of the neural network to be exploited both at the level of the input data as well as at the level of the classification outputs.

Using the architecture depicted in Figure 2, the following advantages can be realized:

1. The system can maintain the probabilistic, continuous advantages of neural networks through both the neural and rule based processing.
2. Neural network outputs feed higher-level IF/THEN rules. Additionally, the results of higher-level rules are fed back to improve classification at the lower, neural levels.
3. The neural network component is functionally decomposed as appropriate whenever clearly separable functions are to be performed. This improves learning and processing time, as well as makes the classifier easier to understand for humans.

In the following paragraphs, details of the techniques used to achieve these advantages are presented.

III.1. The Input Neural Network

An example input neural network is shown in Figure 3. This network is a standard feed-forward network trained using the popular backpropagation algorithm [Rumelhart & McClelland]. For classifying a cell in the GIS image, all of the information from the cells as well as neighboring cells are used as inputs to the network. For example, the network depicted in Figure 3 uses a 25-pixel region. If the GIS data is a visible-wavelength image, the Red, Green, and Blue (RGB) values from each cell are used as inputs. Thus, the depicted network has 75 input units. The number of output units is equal to the number of classes which need to be classified.

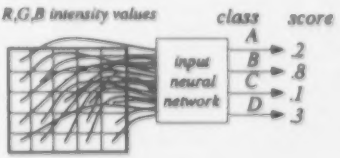

Figure 3. Input Neural Network

As is commonly done [e.g., Ryan, et.al.], a "perfect match" to a class will occur when the activation value of the neuron corresponding to that class equals 1.0 while all of the other output units have an activation of 0.0. For example, the network in Figure 3 is classifying the center cell as being in class "B."

III.2. Adding IF/THEN Rules

As discussed above, a simple neural network connected to a group of GIS raster cells is not likely to be successful at the complete classification task. This is the case because contextual information needed to distinguish between groups of pixels that have similar optical characteristics is needed. In our approach his kind of knowledge is input in the form of IF/THEN rules. The requirements and representation of these rules are described below.

III.2.1. What the IF/THEN Rules Should Represent

There are several categories of contextual information that are relevant to the feature extraction and classification task in raster-based GIS images. Some of these categories are enumerated here:

Connectivity with other Features: In many circumstances, the connection of a region to other points in the image helps to determine the classification of the region. For example, if there is no connection by land between a point of land and a region known to be on a continent, the region can be classified as part of an island. Another example is that a shallow water area not connected by appropriate waterways to the ocean should not be classified as a suitable habitat for salmon eggs.

Distances to other Features: The distance between a region and other features is also important in the classification problem. For example, a sandy shore that is far from the ocean would not be classified as a place at which to find sea turtles nesting.

Properties of the neighborhood of a Region: Similar regions appearing in the neighborhood of a region help to classify certain types of features. For example, properties such as the spatial density of a color or the shape of a cluster of similar pixels are useful. Examples include the differentiation between a cloud and a region covered by snowfall.

Classification of Adjacent Regions: Local context is also important in classifying regions. For example, for a region to be in the "shoreline" class, adjacent regions should also fit together in the form of the shoreline.

The last two contextual properties have been addressed elsewhere, such as in [Ryan, et.al.], and are usually addressed using clustering and filtering of similarly-classified regions. We will focus on the first two issues in the remainder of this paper.

III.2.2 Format for the IF/THEN GIS Rules

Our approach represents the various classes of interest in a heterarchical, object-oriented format, using IF/THEN production rules to express the classification knowledge. The class heterarchy begins with a set of low-level classes for which no rules are needed. Example classes include WATER, PLANTS, WHITE-AREA, etc. Subclasses of each of these will be represented as "children" in the object-oriented representation. For example, OPEN-SEA and STREAM would be subclasses of WATER.

The IF/THEN rules directly refer to the types of contextual knowledge that are of use in classifying the GIS data. For example, the length of a path to another feature is a useful contextual clue. This concept is represented in the rules as LENGTH-OF-PATH-TO. The rule format allows concepts such as LENGTH-OF-PATH-TO to be used in either of two ways. The first way is used when the expert supplying the rules quantitatively knows the relevance of the concept. For example, a marine biologist may know that mammal species X can be found on shorelines up to 2 kilometers from the deep sea. A corresponding rule is:

```
rule 1:
IF (CLASS = shore) and
   (LENGTH-OF-PATH-TO deep-sea < 2)
THEN (CLASS = sea-shore)
ELSE (CLASS = inland-shore)
```

This type of rule is called a *direct-decision* rule, because it implies a direct assignment of classification. The second type of rule is used when a quantitative constraint is not known, but it is known that the concept is relevant to classification. An example of this type of rule is:

```
rule 2:
IF (CLASS = shore)
THEN (LENGTH-OF-PATH-TO deep-sea)
DISTINGUISHES-BETWEEN
  (class = sea-shore) AND
  (class = inland-shore)
```

This type of rule is called a *neural-guidance* rule, because it indicates additional contextual knowledge that can be used by the neural network.

III.3. Interfacing the IF/THEN Rules to the Neural Network

The technique for interfacing the IF/THEN rules to the neural network is crucial to optimal performance of the overall classification process. This step is technically challenging because the IF/THEN rules represent conclusions as discrete "yes or no" categories, whereas neural networks maintain continuous-valued scores for all categories. Our approach chooses to allow this probabilistic, continuous nature to exist as long as possible through the decision-making thread, avoiding errors from premature quantization of the available information [Wozencraft & Jacobs]. This choice maintains the advantages of neural net processing demonstrated by "connectionist production systems" [Touretzky & Hinton, Gallant, Saito & Nakano], while maintaining the efficiency of the explicitly rule-based mapping from IF to THEN parts. Additionally, it allows information derived via the IF/THEN rules to be fed back to the neural network, leading to improved performance at that level.

III.3.1 Interfacing Domain Concepts to the Neural Network

Domain concepts are the parameters such as LENGTH-OF-PATH-TO that appear in the IF/THEN rules, but must be derived from data in the GIS image. If completely accurate vector-based data were available, these concepts could often be obtained directly. Another approach would be to include a conversion from raster to vector as part of the classifier. Without perfect conversion, however, path lengths and other context clues could be badly distorted, due to well-known format-conversion problems [Wang].

An improved extraction of domain concepts can be obtained by treating the classification scores as shown in Figure 2 as *probabilities* that the cell is of the respective class. This is in the spirit of the unified vector/raster format proposed in [Wang]. Using Communication-theoretic techniques [Wozencraft & Jacobs], the expected path length or other contextual clue value conditional on the probabilities of each cell, can be found and stored in a layer of the GIS image. The context clue values will therefore be expressed probabilistically, providing an improved resistance to noise and missing data.

We have developed and implemented the algorithms to do this. The algorithms make use of several assumptions, such as the form of the probability density functions. This allows the computation to be done in a local, network-oriented fashion which grow slightly more than linearly with the size of the input neural network. For example, consider the tiny 3x3 image shown in Figure 4a. Suppose that we wish to compute the path length from region 7 to region 6 through water. The probabilities that each region is water, as determined by the traditional neural network are shown in Figure 4b.

1	2	3
4	5	6
7	8	9

Figure 4a. 3 x 3 Region Image

.01	.6	.9
.7	.01	.72
.8	0	.6

Figure 4b. Probabilities of Water in Each Region

Using the path-length approach we developed, the expected path length is 3.7. This is somewhat shorter than the "least resistance" path through regions 7, 4, 2, 3, and 6, because of the non-zero probabilities that some of the shortcut regions are water.

III.3.2. Interfacing Direct Decision Rules to the Neural Network

Direct Decision rules express an assignment of classification to a region based on the lower-level classification of the region and additional domain knowledge. A discrete approach to implementing these rules would be to choose the most likely classification for the region, find the expected value for the domain concept, then use the rules explicitly to assign a classification. However, this approach would throw away the continuous knowledge obtained by the neural network (such as how well the second-best class was matched), which could be of use in further sub-classification. Our approach once again makes use of probabilistic techniques, assigning classification scores using the product rule for conjunctive probabilities

[Wozencraft & Jacobs]. For example, consider the neural network shown in Figure 5.

Assume that there are three classes of interest: water, land, and shore, and that the neural network assigned the probabilities 0.6, 0.4, and 0.2 to these classes, respectively.

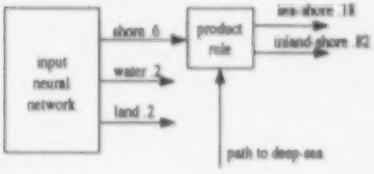

Figure 5. Implementation of Direct Decision Rules.

Next, consider the results of applying rule 1, reprinted here, to these scores:

rule 1:

```
IF (CLASS = shore) and
   (LENGTH-OF-PATH-TO
                deep-sea < 2)
THEN (CLASS = sea-shore)
ELSE (CLASS = inland-shore)
```

Using the new approach, suppose that the expected value of the LENGTH-OF-PATH-TO deep-sea is 3.0, with variance 2.0. If we treat the 0.6 score as a probability that the class is SHORE, Rule 1 implies that the probability of SEA-SHORE is approximately 0.3, yielding the classification scores shown in Figure 5.

III.1.3.3 Interfacing Neural Guidance Rules to the Neural Network

Neural guidance rules are interesting because they indicate that a domain concept is relevant to classification, but do not indicate *how* it is relevant. This indicates that the classification system must learn the relevance of the concept. One obvious approach to this problem would be to add an additional input to the neural network for each domain concept indicated in any rule. This approach theoretically could work, but introduces drawbacks including:

1. The network must re-learn, for each situation, which of the domain concepts are relevant to it, even though this information is explicit in the rule.

2. The network complexity grows enormously if there are many neural-guidance rules.

Our approach is to add a new, small network that learns to correct the classification of the original, simple network on the basis of the contextual knowledge. This approach keeps complexity low, because several small networks are easier to train and faster to process than one larger network. Additionally, each neural network in the architecture performs a clearly-defined task, making understanding its behavior considerably easier. This hierarchical architecture for performing classification is similar to the approach described in [Thacker & Mayhew]. An example of the use of a neural-guidance rule is shown in Figure 6.

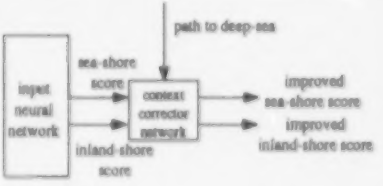

Figure 6. Implementation of Neural Guidance Rules.

On the left is the usual classifier that has been trained to distinguish between the subclasses of SEA-SHORE and INLAND-SHORE. Its performance is of course, suboptimal, because it has no knowledge about the path to the open sea. Due to Rule-2, however, the classification results of this network are fed to the score-corrector network on the right, along with the probabilistic path-to-deep-sea value for the cell being classified.

IV. A Proof of Concept Implementation

We have implemented a demonstration of the classifier at Sedona Scientific that runs on the Hewlett-Packard 9000/700-series UNIX workstation. The software currently accepts raster images from the GRASS [Westervelt] GIS system, and demonstrates a quantitative advantage of using the new method. The classification problem we selected for this demonstration is the remotely sensed image shown in Figure 7.

This is a Landsat photograph used to demonstrate the capabilities of that remote-sensing platform [EOSAT]. This

image was divided into a 64 by 64 grid of regions to be classified, providing classification regions 2.8 kilometers per side. The reduced image, shown with a gray-scale representation, is shown in Figure 8.

Figure 7. Original GIS Image.

Figure 8. Regions for Classification Extracted from Original Image.

The objective of this demonstration was to classify regions into one of the classes of the hierarchy of Figure 9.

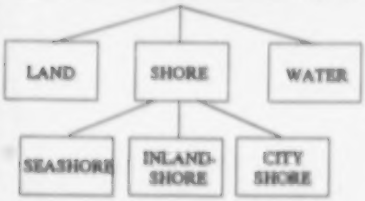

Figure 9. Classification Hierarchy for Example.

Training and test sets each containing approximately 100 regions were selected interactively. We wished to demonstrate that our approach provides superior classification compared to a traditional neural network approach.

To introduce contextual knowledge into the classification system, the following rule was considered:

```
rule 1:
IF (CLASS = shore)
THEN (LENGTH-OF-PATH-TO deep-sea)
DISTINGUISHES-BETWEEN
    (class = sea-shore) AND
    (class = inland-shore)
```

According to the algorithm described in Section C.1.3, the improved classifier architecture is shown in Figure 10. Note that the only classifications affected by this rule are "sea shore" and "inland shore."

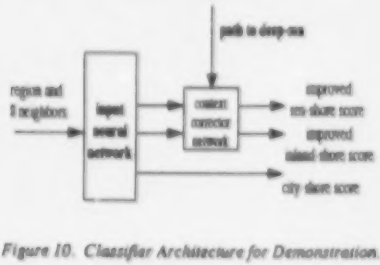

Figure 10. Classifier Architecture for Demonstration.

The test examples were run both with a single, large neural network and with the improved neural network architecture we propose. The results are shown in Figure 11. Note that the traditional neural network performed very poorly for the "inland shore" class, correctly classifying only 43 percent of the test examples. This could be expected, because the pixel attributes of "inland shore" and "sea shore" are quite similar.

As can be seen in the figure, the results from the augmented neural network classifier are quite encouraging. In fact, the classifier correctly classified 100 percent of the "inland shore" examples for this test set used. Some of the preliminary conclusions which can be reached from this demonstration are:

1. The new approach provides superior accuracy than an approach with no high-level domain knowledge.

2. Training the input network independently of the score correctors is a feasible technique to decompose the learning and processing problem.

3. The complexity of the new approach is less than that of a larger, homogeneous network with more inputs.

4. The new approach is a general and systematic way to integrate high- and low-level knowledge.

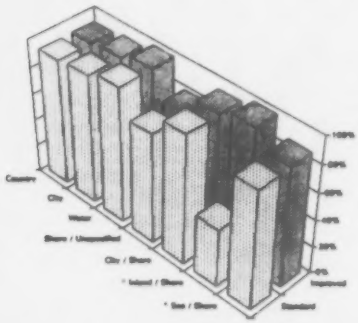

*Figure 11. Comparison Between Traditional and Improved Classifiers. (*Denotes Class Affected by IF/THEN Rule)*

In further work, we are applying the new neural network classification system to a variety of images to study its applicability and collect a more complete set of domain concepts. The hope is that a library of domain concepts can be constructed to allow rapid prototyping of classification systems for a wide variety of GIS applications. We also plan to obtain classification benchmark images to compare the results of the improved neural architecture to other neural and classical classification techniques.

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Alpine Geomorphology in Selwyn Mountains, Southeastern Yukon: Using a GIS for Terrain Analysis

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Abstract

A detailed terrain analysis of an alpine area in the southeastern Yukon is in progress using a digital elevation model from a 1:50,000 digital topographic map, and scanned surficial geology and bedrock geology maps. The aim is to identify the environmental controls on alpine processes, for example, where do glaciers, talus slopes, or avalanche tracks occur within the mountains? Alpine geomorphic processes are controlled by factors such as climate, elevation, slope, aspect, and bedrock type; for example, the distribution of alpine glaciers on Baffin Island has been shown to be controlled primarily by elevation, while aspect, prevailing wind direction, and windward landforms may also be important. A digital elevation model (DEM) of the Anderson Lake map area of the Selwyn Mountains (105H/10) was produced from a digital topographic map obtained from the Surveys, Mapping and Remote Sensing Sector, EMR Canada, using a package called PANACEA. Modelling of the digital elevation model was done within SPANS to produce slope steepness and slope aspect maps. The surficial geology map (Dyke, 1990) and bedrock geology map (Green et al., 1966) were scanned, processed within ARC-INFO, and then imported into SPANS. By overlaying these maps, information can be extracted on alpine landforms and insight can be gained into how bedrock lithology, slope, aspect, and elevation control the formation and distribution of glaciers, rock glaciers, talus slopes, and avalanches. Preliminary results will be presented in the poster.

Géomorphologie Alpine des Montagnes Selwyn, Yukon: Analyse du Terrain à l'aide d'un SIG

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À l'aide d'un modèle numérique de terrain (échelle 1:50,000), des cartes numériques de la géologie et de la géologie de surface, une analyse détaillée du terrain d'une zone alpine du sud-est du Yukon est présentement en cours. L'objectif est d'identifier des contrôles environnementaux sur des processus alpins, par exemple, quelle est la distribution des glaciers, des talus, ou des avalanches dans les montagnes? Les processus géomorphologiques alpins sont controllés par des variables comme le climat, l'élévation, la valeur des pentes, l'aspect, et la géologie. Par exemple, on a montré que la distribution des glaciers alpins sur l'ile de Baffin est controllée principalement par l'élévation; l'aspect, la direction du vent, et la forme du sol en amont peuvent aussi être importants. Un modèle d'élévation numérique de la région du lac Anderson (105H/10) a été produit à l'aide d'une carte topographique numerique provenant du Secteur des levées, de la cartographie et de la télédétection, EMR Canada, en utilisant le logiciel PANACEA. On a produit des cartes de pentes et d'aspect avec le modèle d'élévation numérique. Les cartes de géologie de surface (Dyke, 1990) et de géologie (Green et al., 1966) ont été numérisées à l'aide d'un balayeur optique, traitees dans ARC-INFO, et importées dans SPANS. En superimposant ces cartes, on peut voir comment la géologie, l'élévation, l'aspect, et la grandeur des pentes controllent la formation et la distribution des glaciers, des glaciers rocheux, des pentes de talus, et des avalanches. Les résultats préliminaire seront présentés par affiche.

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- geographic information systems
- spatial information management

For over 100 years, the Institute has played an important role in the development of Canada. From the surveys of Western Canada for land settlement, to working closely with government and industry in mapping the second largest country in the world, the CISM has helped Canada become a world leader in surveying and mapping.

The Canadian Institute of Surveying and Mapping is proud of its heritage and, through the support of its enthusiastic membership, continues the tradition of excellence to meet the future needs of the geo-scientific communities.

BECOME A MEMBER AND RECEIVE:

- CISM /OURNAL ACSGC, an internationally respected surveying and mapping quarterly publication:

  refereed scientific and technical papers
  Industry news
  general news
  new products
  book reviews

- discounts on registration to conferences, symposia, meetings, workshops and seminars
- discounts on proceedings, books and publications
- mailing list service, access and special rates (3000 members/subscribers; 15 000 general data base)
- mail distribution service, special rates on general or targeted distribution
- notices of conventions, symposia, meetings, workshops and seminars, nationally and internationally
- access to a network of professional contacts, locally through your branch and nationally through conferences and the CISM /OURNAL ACSGC
- opportunities for continuing education
- opportunities for professional development
- annual directory
- recognition of achievement through awards
- opportunity to be a leader in your profession
- discounts for and opportunity to attend the premier surveying and mapping exhibitions
- referral service, surveying and mapping information
- discounts on professional memorabilia
- insurance, group plan

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING

ASSOCIATION CANADIENNE DES SCIENCES GÉODÉSIQUES ET CARTOGRAPHIQUES

Fondée en 1882, l'ACSGC est le premier organisme national à but non lucratif du domaine des levés et de la cartographie. Comptant plus de 3 000 membres et d'abonnés canadiens et étrangers, l'ACSGC dessert une communauté multi-disciplinaire en tant que principal du organisateur d'activités techniques, scientifiques, professionnelles et de recherche.

Les membres de l'Association proviennent du secteur privé, de tous les niveaux de gouvernement et des établissements d'enseignement. Par l'entremise de sa publication trimestrielle, de conférences nationales annuelles, de symposiums thématiques, de prix, de subventions et de bourses d'études, l'Association est la tribune idéale pour l'échange de connaissances en:

- arpentage
- photogrammétrie
- cartographie
- levés d'ingénierie
- télédétection
- levés géodésiques
- hydrographie
- levés miniers
- levés géophysiques
- systèmes d'information géographique
- gestion d'information à référence spatiale

Depuis plus de 100 ans, l'Association joue un rôle important dans le développement du Canada. Des levés de l'Ouest canadien pour la colonisation, jusqu'à l'étroite collaboration avec le gouvernement et l'industrie pour la cartographie du deuxième plus grand pays au monde, l'ACSGC a aidé le Canada à devenir un leader mondial en levés et en cartographie.

L'Association canadienne des sciences géodésiques et cartographiques est fière de son héritage et, grâce à l'appui de ses membres enthousiastes, poursuit sa tradition d'excellence pour rencontrer les besoins futurs des communautés géo-scientifiques.

AVANTAGES D'ETRE MEMBRE; VOUS RECEVEZ:

- CISM JOURNAL ACSGC, publication trimestrielle qui jouit d'une excellente réputation sur le plan international:
  - articles scientifiques et techniques soumis
  - nouvelles de l'industrie
  - informations générales
  - nouveaux produits
  - critiques de livres
- réductions sur les inscriptions aux conférences, colloques, réunions, ateliers de travail et séminaires
- réductions sur les rapports, livres et publications
- service d'envoi, accès et tarifs spéciaux (3000 membres/abonnés base de 15000 données générales)
- service de distribution du courrier, tarifs spéciaux sur la distribution générale ou ciblée
- notification des congrès, colloques, réunions, ateliers de travail et séminaires se déroulant sur le plan national et international
- accès à un réseau de contacts professionnels, localement par l'intermédiaire de votre Section, et sur le plan national grâce aux conférences et à la revue CISM JOURNAL ACSGC
- possibilités de formation continue
- possibilités de développement professionnel
- répertoire annuel
- reconnaissance des réalisations grâce aux récompenses
- possibilité d'être un chef de file dans votre profession
- réductions, de même que possibilité d'assister aux plus importantes expositions en matière de sciences géodésiques et cartographiques
- service de références, informations relatives aux sciences géodésiques et cartographiques
- réductions sur les souvenirs professionnels
- plan d'assurance groupe

MEMBERSHIP IN CISM IS YOURS . . .
READ ON . . .

MEMBERSHIP IN CISM

- brings you the CISM *Journal* ACSGC, four times a year
- keeps you abreast of new development in the surveying and mapping sciences
- helps you develop and maintain contacts with other professionals in your field and in related sciences
- helps strengthen the surveying and mapping community in Canada
- entitles you to member discounts on purchase of CISM publications and on registering for CISM conferences and seminars

HOW YOU MAY BECOME A MEMBER

The following types of membership are offered:

Member

The requirement is involvement in the practice of surveying and mapping or an interest in the development and advancement of the surveying, mapping and associated sciences.

Student Member

The requirement is enrolment as a full-time student at a recognized university or technical college in a program of studies in the surveying, mapping or related sciences.

Sustaining Member

Applies to any corporation, organization or person that is interested in, or supports, the objects of the Institute.

APPLICATION FOR MEMBERSHIP

I hereby make application for admission to the Institute as a

GST # R122181403

Sustaining		Student	
❑ Member	$95.00	❑ Member	$230.00	❑ Member	$40.00
+ 7% GST	6.65	+ 7% GST	16.10	+ 7% GST	2.80
Total	101.65	Total	246.10	Total	42.80

and, agree to abide by the constitution and by-laws of the Institute.

Full Name (Print) _____

Home Address _____

_____ Postal Code _____ Tel. (Home) _____

Work Address _____

_____ Postal Code _____ Tel. (Work) _____

Mailing Address: ( ) Home ( ) Work

Professional and Technical Qualifications (circle)

1. Surveying Engineer
2. Commissioned Land Surveyor
3. Professional Engineer
4. Geodesist
5. Cartographer
6. Hydrographer
7. Photogrammetrist
8. Remote Sensing Specialist
9. Technologist
10. Student
11. Other (specify)

Field of Interest (number according to degree, 1,2,...)

( ) Cartography
( ) Control Surveying
( ) Engineering Surveying
( ) Geodesy
( ) Hydrography
( ) Land Information Management
( ) Land Surveying
( ) Mining Surveying
( ) Photogrammetry
( ) Remote Sensing
( ) Other (Specify)

Education: ( ) High School ( ) Technical/Community College ( ) University

Preferred Language: ( ) English ( ) French

Signature _____ **Date** _____

Please attach payment to application form and forward to:

Canadian Institute of Surveying and Mapping, PO Box 5378, Station F, Ottawa, Canada K2C 3J1

FACULTY CERTIFICATE

I certify that the applicant is a full time student in the

_____ Program at

_____ University/College

Signed _____

Name _____

Title

UN STATUT DE MEMBRE DANS L'ACSGC VOUS INTÉRESSE . . . CONTINUEZ A LIRE . . .

LES MEMBRES DE L'ACSGC

- reçoivent la revue CISM *Journal* ACSGC régulièrement quatre fois par année
- sont tenus au courant des nouvelles techniques et des progrès réalisés dans les domaines des sciences géodésiques et cartographiques
- établissent et maintiennent des contacts avec ceux qui oeuvrent dans leurs disciplines et dans d'autres sciences connexes
- aident à renforcer la communauté des sciences géodésiques at cartographiques au Canada
- profitent d'une réduction de prix pour des publications de l'ASSGC et pour le prix d'inscription aux congrès et séminaires de l'ACSGC

COMMENT DEVENIR MEMBRE

Vous pouvez adhérer à l'association selon les catégories suivantes

Membre

Le prérequis exige une implication au niveau de la pratique des levés et de la cartographie ou un intérêt dans le développement et l'avancemnt des sciences géodésiques, cartographiques ou connexes.

Membre étudiant

Le prérequis exige l'inscription à titre d'étudiant à plein temps à une université reconnue ou un collège technique dans un programme d'études dans les sciences géodésiques, cartographiques ou connexes

Membre de soutien

Si en qualité de société, d'organisme ou d'individu vous êtes intéressé à supporter les objectifs de l'association

FORMULE D'ADHÉSION

Je demande, par la présente, à faire partie de l'association à titre de

No de TPS R122381403	**Membre**	**Membre de soutien**	**Membre étudiant**
❑ **Membre**	95.00$	❑ **de soutien** 230.00$	❑ **étudiant** 40.00$
+ TPS de 7%	6.65	+ TPS de 7% 16.10	+ TPS de 7% 2.80
Total	101.65	Total 246.10	Total 42.80

et, si ma demande est acceptée, je consens à respecter la constitution et les règlements de l'association.

CERTIFICAT DE LA FACULTÉ

Je certifie que le candidat est un étudiant à plein temps dans le

_____ programme

à l'Université\Collège _____

Signé _____

Nom _____

Titre

Nom et prénom (lettres moulées) _____

Adresse (résidence) _____

_____ Code _____ Tél. (résidence) _____

Adresse (bureau) _____

_____ Code _____ Tél. (bureau) _____

Adresse postale: ( ) Résidence ( ) Bureau

Compétences professionelles et techniques (encerclez la ou les compétences)

1. Ingénieur topographe
2. Arpenteur-géomètre
3. Ingénieur breveté
4. Géodésien
5. Cartographe
6. Hydrographe
7. Photogrammètre
8. Spécialiste en télédétection
9. Technologue
10. Étudiant
11. Autre (spécifiez)

Domaine d'intérêts (numérotez selon les priorités 1,2,...)

( ) Cartographie
( ) Levés de contrôle
( ) Ingénierie des levés d'arpentage
( ) Géodésie
( ) Hydrographie
( ) Gestion de l'information foncière
( ) Arpentage légal
( ) Arpentage minier
( ) Photogrammétrie
( ) Télédétection
( ) Autre (spécifiez)

Etudes ( ) Secondaires ( ) Techniques ( ) Universitaires

Langue préférée ( ) Français ( ) Anglais

Signature _____ Date _____

Prière de joindre le paiement à la formule d'adhésion et envoyer à:

L'Association canadienne des sciences géodésiques et cartographiques (ACSGC)
C.P. 5378, Succursale F, Ottawa, Canada K2C 3J1

Book Rate
Registration Number
424447

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING
Box 5378, Station F, Ottawa, Canada K2C 3J1

ASSOCIATION CANADIENNE DES SCIENCES GÉOMATIQUES
C.P. 5378, Succursale F, Ottawa, Canada K2C 3J1

Canada

Organized by
The Surveys, Mapping and Remote Sensing Sector, EMR Canada

in cooperation with

THE CANADIAN INSTITUTE OF SURVEYING AND MAPPING

ASSOCIATION CANADIENNE DES SCIENCES GÉOMATIQUES

and
the Inter-Agency Committee on Geomatics

Conférence organisée par
le Secteur des levés, de la cartographie et de la télédétection, EMR Canada

en collaboration avec

et
le Comité mixte des organismes intéressés à la géomatique